PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

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PART I.

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ADVERTISEMENT.

THE Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the Council-books and Journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries till the Forty-seventh Volume; the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March 1752. And the grounds of their choice are, and will continue to be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgement of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body,

17725

upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

The Meteorological Journal hitherto kept by the Assistant Secretary at the Apartments of the Royal Society, by order of the President and Council, and published in the Philosophical Transactions, has been discontinued. The Government, on the recommendation of the President and Council, has established at the Royal Observatory at Greenwich, under the superintendence of the Astronomer Royal, a Magnetical and Meteorological Observatory, where observations are made on an extended scale, which are regularly published. These, which correspond with the grand scheme of observations now carrying out in different parts of the globe, supersede the necessity of a continuance of the observations made at the Apartments of the Royal Society, which could not be rendered so perfect as was desirable, on account of the imperfections of the locality and the multiplied duties of the observer.

A List of Public Institutions and Individuals, entitled to receive a copy of the Philosophical Transactions of each year, on making application for the same directly or through their respective agents, within five years of the date of publication.

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A List of Public Institutions and Individuals, entitled to receive a copy of the Astronomical Observations (including Magnetism and Meteorology) made at the Royal Observatory at Greenwich, on making application for the same directly or through their respective agents, within two years of the date of publication.

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ROYAL MEDALS.

HER MAJESTY QUEEN VICTORIA, in restoring the Foundation of the Royal Medals, has been graciously pleased to approve the following regulations for the award of them:

That the Royal Medals be given for such papers only as have been presented to the Royal Society, and inserted in their Transactions.

That the triennial Cycle of subjects be the same as that hitherto in operation: viz.

1. Astronomy; Physiology, including the Natural History of Organized Beings.
2. Physics; Geology or Mineralogy.
3. Mathematics; Chemistry.

That, in case no paper, coming within these stipulations, should be considered deserving of the Royal Medal, in any given year, the Council have the power of awarding such Medal to the author of any other paper on either of the several subjects forming the Cycle, that may have been presented to the Society and inserted in their Transactions; preference being given to the subjects of the year immediately preceding: the award being, in such case, subject to the approbation of Her Majesty.

The Council propose to give one of the Royal Medals in the year 1851 for the most important paper in Astronomy, communicated to the Royal Society after the termination of the Session in June 1847, and prior to the termination of the Session in June 1850, and printed in the Philosophical Transactions.

The Council propose also to give one of the Royal Medals in the year 1851 for the most important paper in Physiology, including the Natural History of Organized

Beings, communicated to the Royal Society after the termination of the Session in June 1847, and prior to the termination of the Session in June 1850, and printed in the Philosophical Transactions.

The Council propose to give one of the Royal Medals in the year 1852 for the most important paper in Physics, communicated to the Royal Society after the termination of the Session in June 1848, and prior to the termination of the Session in June 1851, and printed in the Philosophical Transactions.

The Council propose also to give one of the Royal Medals in the year 1852 for the most important paper in Geology or Mineralogy, communicated to the Royal Society after the termination of the Session in June 1848, and prior to the termination of the Session in June 1851, and printed in the Philosophical Transactions.

CONTENTS.

I. The Bakerian Lecture.—*Experimental Researches in Electricity.—Twenty-fourth Series. By* Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.* . . . . . page 1

II. *Experimental Researches in Electricity.—Twenty-fifth Series. By* Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.* 7

III. *Experimental Researches in Electricity.—Twenty-sixth Series. By* Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.* 29

IV. *Experimental Researches in Electricity.—Twenty-seventh Series. By* Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.* 85

V. *On Periodical Laws discoverable in the mean effects of the larger Magnetic Disturbances. By Lieut.-Colonel* Edward Sabine, *R.A., Treas. & V.P.R.S.* 123

VI. *On the Relation of the Air and Evaporation Temperatures to the Temperature of the Dew-Point, as determined by Mr.* Glaisher's *Hygrometrical Tables, founded on the Factors deduced from the six-hourly observations made at the Royal Observatory, Greenwich. By* John Fletcher Miller, *F.R.S., F.R.A.S., Assoc. Inst. C.E. &c. Communicated by Lieut.-Col.* Sabine, *For. Sec. R.S.* . . . 141

VII. *On the Meteorology of the Lake District of Cumberland and Westmoreland; with a continuation of the Results of Experiments on the Fall of Rain at various heights, up to 3166 feet above the sea level. By* JOHN FLETCHER MILLER, *F.R.S., F.R.A.S., Assoc. Inst. C.E. Communicated by Lieut.-Colonel* SABINE, *For. Sec. R.S.* . . . . . page 149

VIII. *On the Structure of the Membrana Tympani in the Human Ear. By* JOSEPH TOYNBEE, *F.R.S., Fellow of the Royal College of Surgeons of England, Aural Surgeon to St. Mary's Hospital, and Consulting Surgeon to the St. George's and St. James's General Dispensary.* 159

IX. *On the Impregnation of the Ovum in the Amphibia.* (*First Series.*) *By* GEORGE NEWPORT, *F.R.S., F.L.S. &c.* 169

X. *A Mathematical Theory of Magnetism. By* WILLIAM THOMSON, *Esq., M.A., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow. Communicated by Lieut.-Colonel* SABINE, *R.A., For. Sec. R.S.* 243

XI. *A Mathematical Theory of Magnetism.—Continuation of Part* I. *By* WILLIAM THOMSON, *Esq., M.A., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow. Communicated by Lieut.-Colonel* SABINE, *R.A., For. Sec. R.S.* 269

XII. *Magnetic Survey of the Eastern Archipelago. By Captain* C. M. ELLIOT, *of the Madras Engineers. Communicated by Lieut.-Col.* SABINE, *V.P. Treas. R.S. &c.* 287

PHILOSOPHICAL TRANSACTIONS.

I. The Bakerian Lecture.—*Experimental Researches in Electricity.—Twenty-fourth Series.* *By* Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.*

Received August 1,—Read November 28, 1850.

§ 30. *On the possible relation of Gravity to Electricity.*

2702. THE long and constant persuasion that all the forces of nature are mutually dependent, having one common origin, or rather being different manifestations of one fundamental power (2146.), has made me often think upon the possibility of establishing, by experiment, a connection between gravity and electricity, and so introducing the former into the group, the chain of which, including also magnetism, chemical force and heat, binds so many and such varied exhibitions of force together by common relations. Though the researches I have made with this object in view have produced only negative results, yet I think a short statement of the matter, as it has presented itself to my mind, and of the result of the experiments, which offering at first much to encourage, were only reduced to their true value by most careful searchings after sources of error, may be useful, both as a general statement of the problem, and as awakening the minds of others to its consideration.

2703. In searching for some principle on which an experimental inquiry after the identification or relation of the two forces could be founded, it seemed that if such a relation existed, there must be something in gravity which would correspond to the dual or antithetical nature of the forms of force in electricity and magnetism. To my mind it appeared possible that the ceding to the force or the approach of gravitating bodies on the one hand, and the effectual reversion of the force or separation of the bodies on the other, might present the points of correspondence; quiescence

(as to motion) being the neutral condition. The final unchangeability of gravity did not seem affected by such an assumption; for the acting bodies when at rest would ever have the same relation to each other, and it would only be at the times of motion to and fro that any results related to electricity could be expected. Such results, if possible, could only be exceedingly small; but, *if possible*, i. e. if true, no terms could exaggerate the value of the relation they would establish.

2704. The thought on which the experiments were founded was, that, as two bodies moved towards each other by the force of gravity, currents of electricity might be developed either in them or in the surrounding matter in one direction; and that as they were by extra force moved from each other against the power of gravitation, the opposite currents might be produced. Also, that these currents would have relation to the line of approach and recession, and not to space generally, so that two bodies approaching would have currents in the opposite direction as to space generally, but the same as to the direction of their motion along the line joining them. It will be unnecessary to go further into the suppositions which arose concerning these points, or regarding the effect of forced motions either coinciding with, or across the direction of the earth's gravitation, and many other matters, than to say that, as the effect looked for was exceedingly small, so no hope was entertained of any result except by means of the gravitation of the earth. The earth was therefore made to be the one body, and the indicating mass of matter to be experimented with the other.

2705. First of all, a body, which was to be allowed to fall, was surrounded by a helix, and then its effect in falling sought for. Now a body may either fall with a helix or through a helix. Covered copper wire, to the amount of 350 feet in length, was made into a hollow cylindrical helix, about 4 inches long, its internal diameter being 1 inch and its external diameter 2 inches. It was attached to a line running upon an easy pulley, so that it could be raised 36 feet, and then allowed to fall with an accelerated velocity on to a very soft cushion, its axis remaining vertical the whole time. Long covered wires were made fast to its two extremities, and these being twisted round each other, were attached to a very delicate galvanometer, placed about 50 feet aside from the line of fall, and on a level midway with its course. The accuracy of the connection and the direction of the set of the needle, were then both ascertained by the introduction of a feeble thermo-electric combination into the current. Such a helix, either in rising or falling, can produce no deviation at the galvanometer by any current due to the magnetism of the earth; for as it remains parallel to itself during the fall, so the lines of equal magnetic force, which being parallel to the dip, are intersected by the wire convolutions of the descending helix, are cut with an equal velocity on both sides of the helix, and consequently no effect of magneto-electric induction is produced. Neither in rising nor in falling did this helix present any trace of action at the galvanometer; whether the connection with the galvanometer was continued the whole time, or whether it was cut off just before the

diminution or cessation of motion either way, or whether the rising and the falling were made to occur isochronously with the times of vibration of the galvanometer needle. So, though no effect of gravity appeared in the helix itself, still no source of error appeared to arise in this mode of using it.

2706. A solid cylinder of copper, three-fourths of an inch in diameter and 7 inches in length, was now introduced into the helix and carefully fastened in it, being bound round with a cloth so as not to move, and this compound arrangement was allowed to fall as before (2705.). It gave very minute but remarkably regular indications of a current at the galvanometer; and the probability of these being related to gravity appeared the greater, when it was found that on raising the helix or core, similar indications of contrary currents appeared. It was some time before I was able to refer these currents to their true cause, but at last I traced them to the action of a part of the connecting wires proceeding from the helix to the galvanometer. The two wires had been regularly twisted together, but the effect of many falls had opened a part near the middle distance into a sort of loop, so that the wires, instead of being tightly twisted together like the strands of a rope, were separate for 3 feet, as if the strands were open. In falling, this loop opened out more or less, but always in the same manner; and the consequence was that the part of it representing the transverse opening, which was furthest from the galvanometer, travelled over a larger space than the corresponding part nearest the galvanometer. Now had they travelled through equal spaces, the effect of the magnetic lines of force of the earth upon them would have been equal, and no effect at the galvanometer would have been produced; as it was, currents in opposite directions, but of unequal amounts of force, tended to be produced, and a current equal to the difference actually appeared. Such a case is described in my earliest researches on terrestrial magno-electro induction (171.). It is evident that the current should appear in the reverse direction, as the helix and wires are raised in the air, and thus arose the reverse effect described above. Therefore no positive or favourable evidence was supplied in favour of the original assumption by this use of a copper core in the helix.

2707. The copper was selected as a heavy body and an excellent conductor of electricity. On its dismissal, a bismuth cylinder of equal size was employed to replace it as a substance eminently diamagnetic, and a bad conductor amongst metals. Uncertain evidence arose; but by close attention, first to one point and then to another, all the indications disappeared, and then the rising or falling of the bismuth produced no effect on the galvanometer.

2708. An *iron* cylinder was also employed as a magnetic metal, but when made perfectly secure, so as to prevent any motion relative to the helix, it was equally indifferent with the copper and bismuth (2706. 2707.).

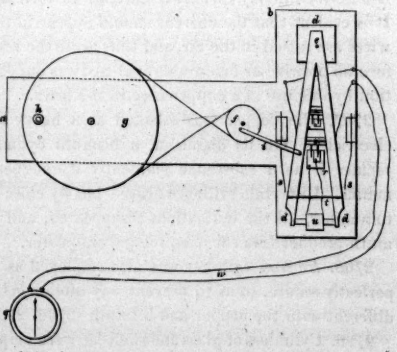
2709. Cylinders of glass and shell-lac were employed as non-conducting substances, but without effect.

2710. In other experiments the helix was *fixed*, and the different substances in the

form of cylinders, three-fourths of an inch in diameter and 24 inches long, were dropped through it, or else raised through it with an accelerated velocity; but in neither case was any effect produced. Rods of copper, bismuth, glass, shell-lac and sulphur were employed. Occasionally these rods were made to rotate rapidly before and during their fall; and many other conditions were devised and carried into effect, but always with negative results, when sources of error were avoided or accounted for.

2711. On further consideration of the original assumption, namely, a relation between the forces, and of the effects that might be looked for consequent upon a condition of tension in and around the particles of the body, which, as we know, are at the same moment the residence of both gravitating and electric forces, and are subject to the gravitation of the earth, it seemed probable that the stopping of the up and down motion (2703. 2704.) in the line of gravity would produce contrary effects to the coming on of the motion, and that, whether the stopping was sudden or gradual; also that a motion downward quicker than that which gravity could communicate, would give more effect than the gravity result by itself, and that a corresponding increase in the velocity upwards would be proportionally effectual. In such case a machine which could give a rapid alternating up and down motion, might be very useful in producing many minute units of inductive action in a small space and moderate time; for then, by proper commutators, the accelerated and retarded parts of each half-vibration could be separated and recombined into one consistent current, and this current could be sent through the galvanometer during the time its needle was swinging in one direction, and afterwards reversed for the time of a swing in the other direction; and so on alternately until the effect had become sensible, if any were produced by the assumed cause.

2712. The machine which I had made for this purpose is that described in the last Series of these Researches (2643.), the electromagnet, the experimental core and the rod which carried them being removed:—*a*, *b*, *c* frame-board; *d*, *d*, *d* wooden lever, of which *e* is the axis; *f* the crank-wheel, and *g* the great wheel with its handle *h*; *i* the bar connecting the crank-wheel and lever; *q* the galvanometer; *r* the commutator; *w*, connecting wires; *s*, *s* springs of brass or copper; *t* a copper rod connecting the two arms of the lever to give strength; *u* the hollow helix fixed, or moveable at pleasure. The plan is to a scale of one-fifteenth. Being on a



moveable frame, it could be placed in any position. The cylinder of metal or other substance to be submitted to its action, was 5½ inches long and three-fourths of an inch in diameter, and was firmly held between the ends *d*, *d* of the lever arms. The extent of the alternating motion was 3 inches. A hollow cylindrical helix *u*, 2½ inches in length, and of such internal diameter that the cylinders could complete their rapid journeys to and fro within it without any danger of striking against its sides, was constructed, containing 516 feet of covered copper wire; this cylinder could be either fixed immoveably or attached firmly to the cylinder under experiment so as to move with it. The wires from this helix passed to the commutators and from them to the galvanometer. Part of the momentum of this machine was taken up by springs *s*, *s* (2648.), and converted into the contrary motion; but so much remained undisposed of thus, that great care was required in fixing and strutting to render the action of the whole very steady, or else derangement quickly occurred at the cylinder and helix, and electro-currents were frequently produced.

2713. The employment of cylinders of iron, copper and other substances in this machine, was competent to produce electro-currents in various ways. Thus, iron might produce magneto-electric currents consequent upon its polar condition under the influence of the earth; these it would be easy to detect and separate by the use of adjusted magnets, which should neutralize or reverse the lines of magnetic force passing through the iron. Currents like those induced in copper cylinders and good conductors (2663. 2684.), might be produced by the earth's action; but as the lines of gravitating force and of terrestrial magnetic force are inclined to each other, these might be separated by position; and it appeared that there was no source of error that might not by care be eliminated. I will not occupy time by describing how this long lesson of care was learned, but pass at once to the chief results.

2714. The copper cylinder (2712.) was placed in the machine, and the helix fixed immoveably around it, the whole being in such a position that the cylinder should be vertical, and move up and down parallel to the line of gravitating force within the helix. However rapidly the machine was worked, or whatever the position of the commutator, there was no result at the galvanometer. Cylinders of bismuth, glass, sulphur, gutta percha, &c., were also employed, but with the same negative conclusion.

2715. Then the helix was taken from its fixed support and fastened on to the copper cylinder so as to move with it, and now very regular and comparatively large effects were produced. After a while, however, these were traced to causes other than gravity, and of the following kind. The helix was fixed at one end of a lever, at a point 22 inches from its axis, and being 2 inches in diameter its wires on one side were only 21 inches, and on the other side 23 inches from this axis. Hence, in vibrating these parts travelled with velocities and through spaces which are as 21 : 23. When therefore their paths were *across* the lines of magnetic force of the earth, electro-currents tended to form in these different parts proportionate in amount or

strength to these numbers; and the differences of these currents being continually gathered up by the commutators, were made sensible at the galvanometer. This was rendered manifest by placing the machine so, that though the plane of vibration was still vertical, the place of the helix was just under the centre of motion, and the central line of the helix therefore, instead of being vertical, was horizontal. Now the convolutions of the helix cut the lines of magnetic force in the most favourable manner; and the consequence was that the commutators were not required, for a single motion of the helix in one direction was sufficient to show at the galvanometer the magneto-electric currents induced. If, on the contrary, the plane of motion was made horizontal, then no current was produced by any amount of motion; for though the helix was as horizontal as, and not sensibly more so than before, yet the parts of the convolutions which intersected the magnetic lines of force (being the upper and the lower parts) now moved with exactly equal velocity, and no differential result was produced.

2716. The former small result (2715.) was therefore probably dependent upon an effect of this kind; and this was confirmed by placing the machine in such a position that the axis of the moving copper cylinder and helix should in its medium position be parallel to the line of the dip, and then no effect was produced. Other bodies in the same position were equally unable to produce any effect.

2717. Here end my trials for the present. The results are negative. They do not shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists.

Royal Institution,
July 19, 1850.

II. *Experimental Researches in Electricity.—Twenty-fifth Series.* *By* MICHAEL FARADAY, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.*

Received August 15,—Read November 28, 1850.

§ 31. *On the magnetic and diamagnetic condition of bodies.*

¶ i. *Non-expansion of gaseous bodies by magnetic force.* ¶ ii. *Differential magnetic action.* ¶ iii. *Magnetic characters of Oxygen, Nitrogen and Space.*

¶ i. *Non-expansion of gaseous bodies by magnetic force.*

2718. THERE can be no doubt that the magnetic force, the diamagnetic force, and the magneoptic or magnecrystallic force, will, when thoroughly understood, be found to unite or exist under one form of power, and be essentially the same. Hence the great interest which exists in the development of any one of these modes of action; for differing so greatly as they do in very peculiar points, it is hardly possible that any one of them should be advanced in its illustration or comprehension, without a corresponding advance in the knowledge of the others. Stimulated by such a feeling, I have been engaged with PLÜCKER, WEBER, REISCH and others, in endeavouring to make out, with some degree of precision, the mode of action of diamagnetic as well as magnecrystallic bodies; and the recent investigation (2640, &c.) and endeavour to confirm the idea of polarity in bismuth and diamagnetic bodies, the reverse of that in a magnet or in iron bodies, was one of the results of that conviction and desire.

2719. Having failed however to establish the existence of such an antipolarity, and having shown, as I think, that the phenomena which were supposed to be due to it are in fact dependent upon other conditions and causes, I was induced, in the search after something precise as to the nature of diamagnetic bodies, to examine another idea which had arisen in consequence of the development of magnetic and diamagnetic phenomena amongst gaseous substances: this thought, with some of the results which have grown out of it during its experimental examination, I purpose making the subject of the present paper.

2720. BANCALARI first showed that flame was diamagnetic*. The effect, as I proved, was due chiefly to the heated state of gaseous portions of the flame†; but besides that, it appeared that at common temperatures diamagnetic phenomena could

* Philosophical Magazine, 1847, vol. xxxi. pp. 401, 421. † Ibid. pp. 404, 406.

be exhibited by gases; and also that in their production the gases differed very much one from another*; so that, taking common air, for instance, as a standard, nitrogen, and many other gases, were strongly diamagnetic in relation to it, whilst oxygen took on the appearance of a magnetic body; for *they* were repelled from, while it was attracted to, the place of maximum force in the magnetic field.

2721. Recalling the general law given respecting the action of magnetic and diamagnetic bodies (2267, 2418), namely, that the former tended to go from weaker to stronger places, and the latter from stronger to weaker places of magnetic power, and applying it to such bodies as the gases, which are at the same time both highly elastic and easily changed in bulk by the superaddition of very small degrees of force, it would seem to follow, that if the particles of a diamagnetic gas tended to go from strong to weak places of action, in consequence of the direct and immediate effect of the magnetic power on them, then such a gas should tend to become enlarged or expanded in the magnetic field. For the amount of power by which the particles would tend to recede from the axis of the magnetic field, would be added to the expansive force by which they before resisted the pressure of the atmosphere; that pressure would therefore be in part sustained by the new force, and expansion would of necessity be the result. On the other hand, if a gas were magnetic (as for instance oxygen), then the force cast upon the particles, by such a direct and immediate action of the magnetic power upon them, would urge them *towards* the axis of the magnetic field, and so coinciding with, and being superadded to the pressure of the atmosphere, would tend to cause contraction and diminution of bulk.

2722. If such supposititious cases were to prove true, we should then be able to arrive at the knowledge of the real zero-point (2416, 2432, 2440)†, not amongst gases only, but amongst all bodies, and should be able to tell whether such a gas as oxygen were a magnetic or a diamagnetic body, and also able to range individual gases and other substances in their proper places. And though I had originally endeavoured to ascertain whether there was any change in the bulk of air in the magnetic field, and found none, still PLÜCKER's statement that he has obtained such an effect‡, and the great enlargement of knowledge respecting the gases which since then we have acquired relating to their diamagnetic relations, and especially of the great difference which exists between them, encouraged me to proceed.

2723. I first endeavoured to determine whether there was any affection of the layer of air (or other gas) immediately in contact with the magnetic pole, which, either by the consequent expansion or contraction of that layer, could render it able to affect the course of a ray of light and thus make manifest the changes occurring within. A metal screen, with a pin-hole in it, was set up before the flame of a bright lamp in a dark room, and thus an artificial star or small definite luminous object was formed.

* Philosophical Magazine, 1847, vol. xxxi. p. 409.

† Ibid. p. 420.

‡ Annales de Chimie, 1850, xxix. p. 134.

Forty-six feet from it was placed the great horseshoe magnet (2247.), ready to be excited by twenty pairs of GROVE's plates; the poles were in a line, so that the ray from the lamp passed for 4 inches close to the surface of the first pole, then through 6 inches of air, and then, for 4 inches, close to the surface of the second pole. A very fine refracting telescope, belonging to Sir JAMES SOUTH, having an aperture of 3 inches and 46 inches focal length, received the ray. The telescope was furnished with a perfect micrometer, so that the smallest change in the place of the luminous image could be observed on the threads. The axis of the telescope was just above the level of the magnetic poles. Not the smallest change in either the character or place of the luminous image could be observed, either on the making or the breaking of the contact between the voltaic battery and the magnetic wire.

2724. As the chief part of the light which came to the telescope consisted of rays which passed at some distance above the magnetic poles, these were cut off by a screen, which rising only one-eighth of an inch above the level of the poles, allowed no ray to pass that was not within that distance. The intensity of the light was of course diminished, and the image was distorted by inflection; still its place was well marked by the micrometer. Not the slightest change in that or any other character occurred in the supervention or the withdrawal of the magnetic force.

2725. The terminals of the magnetic poles were then varied, so that the ray sometimes passed parallel and close to a long right-angled edge, or parallel to and between two right-angled edges, a little above or below them, or over the line joining two hemispherical poles, placed close together (and also in many other ways), but in no case did the magnetic action produce any effect upon the course of the ray.

2726. In another form of the experiment the telescope was dismissed, and a simple card, with a pin-hole $\frac{1}{50}$th or $\frac{1}{100}$th of an inch in diameter, employed in its place. The image of the star of light could be seen through the pin-hole in the dark room, and yet every ray tending to its formation passed within $\frac{1}{50}$th of an inch of the surface of the magnetic pole; still no effect due to the magnetic force could be observed.

2727. By another arrangement of the polar terminations, analogous to one I had formerly employed when experimenting on the diamagnetic relations of the gases*, I was able to surround them with other gaseous substances than air, and subject the ray for 2 inches of its course to these gases whilst under the influence of the magnet. Though the glass of the enclosing vessel disturbed the image of the object, *i. e.* the point of light, yet it was easy to perceive that no additional effect occurred when the magnetism was superinduced.

2728. Oxygen, nitrogen, hydrogen and coal-gas were thus employed; but whether any one of these, or whether air itself was submitted to examination, when in contact with the active pole of a very powerful magnet, it did not appear to be either expanded or condensed to such a degree as to cause any sensible change in its refractive force.

* Philosophical Magazine, 1847, vol. xxxi. pp. 414, 415.

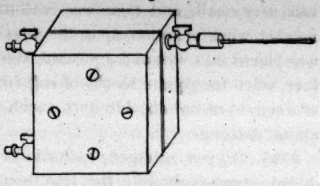
2729. In order to compare the expected result with the real result due to change of volume, I took a bar of iron 7 inches long, and placed it so that the ray from the luminous object in passing to the eye should proceed by the side of the bar at not more than $\frac{1}{10}$th of an inch from it, and then raised the temperature of the bar gradually, until by expanding the air in contact with it, the course of the ray of light was sensibly affected; to do this it required to be exalted many degrees. When the air of the place was at 60° and the iron raised to 100° FAHR., the effect was not distinct. Hence it seemed, that observation of the expected change of volume of the air would be rendered far more sensible by some arrangement, measuring that change directly, than by such means as those referred to above, dependent on refractive force; for it is certain that the change of volume, in a very small quantity of air, raised from 60° to 100°, would be very evident by the former method. On the other hand, it was just possible that if the air or gas was affected by the magnet, it might only be in that film immediately contiguous to the pole; and also that great differences in the degree of change might exist along the *edge* of a solid angle, and along the *sides* of the planes forming that angle. Hence the assumed necessity for examining those parts by a ray of light; and every precaution was taken, by inclining the course of the ray a little more or less to the sides or edges of the poles, and by making the sides or edges very slightly convex, to include every variation of the experiment, that might help to make any magnetic or diamagnetic effect, whether special or local, or general, manifest; but without effect.

2730. I proceeded, as these attempts had failed, to endeavour to determine and compare the *volume* of air subjected to the magnetic force, before and after its subjection; and there seemed to be the greater hope of obtaining some results in this way, provided any such change was a consequence of the action of magnetic power, because air and gases, at a considerable distance from the surface of the magnet, are known to be strongly affected diamagnetically, and because PLÜCKER had already said he had obtained such change of volume (2722.).

2731. The first instrument constructed for this purpose was of the following kind. Two blocks of soft iron, each 1 inch thick and 3 inches square, having filed and flattened surfaces, were prepared; and also a sheet of copper, $\frac{1}{60}$th of an inch in thickness and 3 inches square, having its middle part cut away to within 0·3 of an inch of the edge all round. This plate or frame was then placed between the iron blocks, and the whole held together very tightly by copper screws, so as to make an air-chamber $\frac{1}{60}$th of an inch wide and 2·4 inches square, having the faces of the blocks, which were to become the magnetic poles, for its sides. Three apertures and corresponding passages gave access to the interior of this chamber; small stop-cocks were attached to each. By two of these, any gas, after it had been properly dried, could be sent into the chamber, or swept out of it, by any other entering gas;

and to the third was attached a gauge (2732.) for the purpose of indicating and measuring any change of volume which might occur. The edges of the central copper plate and the heads of the countersunk screws, were touched with white hard varnish, and the chamber thus rendered perfectly tight, under every condition to which it had to be subjected (fig. 1).

Fig. 1.



2732. The gauges were formed of small capillary tubes from 1·5 to 3 inches in length, the diameter in the middle of their length being less than one-half of that at either termination. These were fixed at one end into a small socket, which screwed on to the third, or gauge-cock mentioned above (2731.). A minute portion of spirit, coloured by cochineal, being put into the external end of this gauge, from a slip of wood or glass, immediately advanced to the middle or narrowest part, forming, as it always should do, a single portion of fluid. By shutting the cock, this little cylinder could be easily retained in its place undisturbed during the filling of the air-chamber with gas, and the adjustment of its pressure to equality with that of the atmosphere. On shutting the other cocks and opening the gauge-cock, the gauge was then ready to show any change of volume which the supervention of the magnetic force might cause; but to give it the highest degree of sensibility, it was necessary previously to make the liquid cylinder travel right and left of its place of rest, that the tube might be moistened on each side of the indicating fluid; an effect easily obtained by inclining the chamber to and fro, the gravity of the fluid making it pass one way or the other. But this and many other necessary precautions as to position, temperature, &c., can only be learned from experience.

Fig. 2.

2733. When this box was in its place, it stood between the poles of the great electro-magnet, with the plane of the gas-chamber in the equatorial position; then square blocks of soft iron, resting on the magnet poles, were made to abut and bear against the sides of the box, so that in fact the inner faces of the air-chamber were the virtual magnetic poles, and being 3 inches square were only $\frac{1}{60}$th of an inch apart. Hence, whatever air or gas was within the chamber, would be subjected to a very powerful magnetic action, and could have very small changes in its bulk measured; but it is perhaps necessary to observe, that it would be contained in a field having everywhere lines of equal magnetic power (2463. 2465.).

2734. *Air* was introduced into the box, and when all was properly arranged, the place of the indicating fluid was observed by a microscope. Then the magnet was rendered powerfully active, and there appeared a very slight motion of the fluid, as if the air were a little expanded; on taking off the magnetic force the fluid returned to

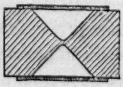
its first place. The same effect recurred again and again. The amount of this change was very small, and there was reason to refer it to the pressure exercised by the magnet, when in action, upon the sides of the iron box; for afterwards, when the box was placed in a vice and squeezed, the same motion in the fluid occurred; and further, when the square blocks of soft iron (2733.) were kept apart by an under block of wood, so as not absolutely to touch and press the box, the effect was reduced to almost nothing.

2735. Oxygen, nitrogen, carbonic acid and nitrous oxide gases, were then introduced successively into the iron box, and with exactly the same result as with air. No difference appeared between oxygen and the other gases, greatly as they differ in magnetic and diamagnetic force and relations. Hydrogen and coal-gas were also subjected to experiment; but when these gases were in the box there was a gradual recession of the indicating fluid, due, as I found, to the absorption of the gases, probably either by the varnish or cement or cork used at the gauge, or at the joints of the box. The delicacy of the gauge was thus made manifest; but when the effect was taken into account, it was found that these gases were equally unaffected in bulk as the other gases by the magnetic influence.

2736. The diameter of the gauge, at the place where the fluid was placed, was rather less than $\frac{1}{100}$th of an inch. An amount of motion equal to $\frac{1}{100}$th of an inch was easily discerned. Comparing these numbers with the capacity of the gas-chamber, it would appear that if the gas in the latter had expanded or contracted to the extent of $\frac{1}{100,000}$th part, the result would have been visible; or any *difference* approaching to this amount, between oxygen and nitrogen or the other gases, would have become sensible, *but no such effects or differences appeared.*

2737. As the establishment of either the *occurrence* or the *absence* of change of volume in gases, when under the magnetic influence, appeared to me to be of great and almost equal importance, I was led to consider whether, in the experiment just described, the circumstance of the gases having been subjected to the magnetic power in a field of equal force (2733.) might not have interfered with the production of the effect sought for; for such a field is that where the diamagnetic phenomena, of solid and liquid bodies, occur in the most unfavourable manner, and where indeed they almost entirely disappear. I therefore constructed another apparatus so that this condition was removed, and in which, if the particles of the diamagnetic gas, by any unknown disposition of the powers in action, tended only to pass from strong to weaker places of force, and being thus incapable of enlargement in the axial direction, would only show that effect equatorially, the opportunity for their doing so should be present.

Fig. 3.



2738. A cylinder of soft iron had the central parts removed in a lathe, until it had assumed the form of an hour-glass, or that represented in fig. 3, which is to a scale of one-third. When placed between the poles of the magnet instead of the former box, it was ex-

pected that the continuation of the iron throughout would prevent any diminution of its length, from the pressure of the poles (2734.), and that the diamagnetic phenomena would be abundantly produced in the parts from whence the iron had been removed. The latter was found to be the fact, for flame, smoke, bismuth and other diamagnetic matter, when placed there, passed equatorially very freely.

2739. A copper tube, 2·5 inches long, made of metal 0·1 of an inch thick, was fitted to the iron, so that when in its place it should occupy the position represented (fig. 3), and could easily be made perfectly gas-tight by a little soft cement. In this way it formed an annular air-chamber round the iron, which, when measured, was found to have a capacity of rather more than 2 cubic inches, and included the most intense part of the magnetic field. Three stopcocks were fitted into this copper jacket, by two of which gas was passed into and out of the chamber, and the third was appropriated to the pressure-gauge as before. Whilst naked, this apparatus could not be used, because of its ever-varying temperature, and the consequent disturbance and ejectment of the fluid in the gauge; but when clothed in three thicknesses of flannel its temperature was perfectly steady; and by the further use of wooden keys to turn the cocks the apparatus became unexceptionable.

2740. Before proceeding to employ this apparatus with different gases, and in order to obtain some idea of what might be expected by comparing one gas with another, I made a preliminary experiment, dependent on the relative specific gravities of air and hydrogen, of the following nature. It is easy to diffuse a trace of ammonia through the air of a jar, by putting a little paper wetted with a strong solution into it*; and it is equally easy to send a jet of hydrogen, containing the smallest portion of muriatic acid gas, by a horizontal tube into the ammoniated air. When this is done, the course of the light hydrogen in the heavy air is rendered very distinctly visible; and it is seen, on leaving the horizontal tube, to turn at once upwards and to ascend rapidly, becoming wire-drawn in its course, in consequence of its small specific gravity compared to air.

2741. Two hemispherical iron pole terminations, associated with the great magnet, were then placed in contact with each other, so that they might be surrounded either by air or oxygen†, and the jet of hydrogen, delivering at the rate of 6 cubic inches per minute, was placed exactly beneath the axial line, in the centre of the magnetic field. When there was no magnetic force employed the hydrogen rose vertically, breaking against the points where the hemispherical poles touched; but when the magnetic power was on, the stream of hydrogen divided into two parts, moving right and left, and ascended in two streams at a distance from the point of contact. Now this division took place at a certain distance *below* the axial line; and at that point, notwithstanding the ascensive power of hydrogen in air or oxygen, it was constrained to go horizontally by the apparently repulsive power of the magnetic force, and did not in its further course approach nearer to the axial line, but formed a curve concentric

* Philosophical Magazine, 1847, vol. xxxi. p. 415.

† Ibid. pp. 413, 414.

with it, or nearly so, so that the compound streams of gas assumed exactly the shape of a tuning-fork.

2742. When air occupied the magnetic field, the division of the stream of hydrogen was 0·3 or 0·32 of an inch below the axial line. When oxygen was about the poles, then the division of the hydrogen took place as far off as 0·55 of an inch below the axial line. Hence at these distances the power which tended to make the hydrogen pass from the axial line, equatorially in the direction of the radius, was equal to the difference of the specific gravity of hydrogen compared with that of air and oxygen respectively. At lesser distances the power would be much greater; and indeed, if in any experiment the hydrogen was delivered nearer to the axial line, it was blown downwards and away with much force. Calculating with these data, and still assuming that the diamagnetic gases receded from the axial line, in consequence of the direct action of the magnet and that only, causing them to pass from stronger to weaker places of action, I found, as I thought, reason to believe that the more diamagnetic gases, occupying the space within the copper box (2739.), might probably be expanded at least $\frac{1}{60,000}$th part of their volume by the magnetic force. Now the gauges that I employed were sensible when the fluid in them moved the $\frac{1}{100}$th of an inch (2736.), yet that space is only the $\frac{1}{2,580,000}$th part of the capacity of the chamber, and therefore such an expansion as that above would have made it move through 0·4 of an inch; a quantity abundantly sufficient to render the result sensible if the fundamental assumption were correct.

2743. *Air* was first submitted to the power of the great horseshoe magnet, urged by twenty pairs of GROVE'S plates in this apparatus (2739.). The fluid moved very slightly outwards, as if a little expansion occurred on putting on the magnetic force, and returned when the force was taken off. This small effect was found afterwards to be due to compression, occasioned by the tendency of the magnetic poles to approximate (2734.).

2744. *Oxygen* presented exactly the same appearances as common air and to the same amount, so that no effect, due to magnetic or diamagnetic action, was here evident, but only that of the compression observed in the case of air (2743.).

2745. *Nitrogen* gave exactly the same results as oxygen and air. Now nitrogen is probably more diamagnetic than hydrogen, and should therefore have given a striking contrast with oxygen, if any positive results were to be obtained.

2746. *Carbonic acid* and nitrous oxide gases yielded the same negative results, and, as I believe, when the apparatus was in an unexceptionable condition.

2747. There is at the Pharmaceutical Society an excellent electro-magnet, of the horseshoe form, similar in arrangement to our own (2247.), but far more powerful, and this through Mr. REDWOOD I was favoured with the use of, for the repetition of the foregoing experiments at the house of the Society. The iron, which is very soft and good in quality, is a square bar, 5 inches in thickness, and the medium line is 50 inches in length. It has 1500 feet of copper wire, 0·175 of an inch in thickness,

coiled round it, and arranged (when I used it) in one continuous length. The moveable terminal pieces for the poles are massive in proportion to the magnet. Eighty pairs of GROVE's plates were used to excite this magnet, and as it was found, by preliminary trials, that these were most powerful when arranged as four twenties, with their similar ends connected, they were so used, constituting a battery of twenty pairs of plates, in which each platinum plate was 4×9 inches in the immersed part, and therefore presented 72 square inches of surface towards the active zinc.

2748. On repeating the former experiments (2743.) the effect of pressure was again evident, and it was manifest that the magnet itself, though 5 inches in thickness, was a little bent by the mutual attraction of its poles. The effect was very small, because of the unity of the iron core passing through the centre of the experimental gas-chamber (2738.). It was the only effect indicated by the gauge, and was the same for all the gases; and when allowance was made for it, nothing remained to indicate any change in volume of the gas itself.

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2749. *Air*, *oxygen*, *nitrogen*, *carbonic acid* and *nitrous oxide* were submitted, in varying order, to the effect of this very powerful magnet, but not the slightest trace of change of bulk in any of them appeared.

2750. I think that the experiments are in every respect sufficient to decide that these gases, whether they are considered as magnetic or diamagnetic bodies, or whether they include bodies of both classes (for oxygen is in striking contrast to the rest), are not affected in volume by the magnetic force, whether in fields of equal power (2737.), or in places where the power is rapidly diminishing. I think this decision very important in relation to the true nature of the magnetic force, either as existing in, or acting upon the particles of bodies; and as in the magnetic field the force exhibits itself, not as a central but as an axial power, so the further distinction of the phenomena, into such as are related to the axial direction (2733.), and such as are related to or include the equatorial direction (2737.), is not unimportant, for they show that the particles do not tend to separate either parallel to the lines of magnetic power, or in a direction perpendicular to these lines. Without the experiments, the mind might have considered it very possible that one of these modes of expansion might have occurred and not the other.

2751. No doubt it is true, that even yet changes in volume in these directions may occur, provided the change in one direction is expansion and in the other contraction, and that these are in amount equal to each other. It was partly in reference to such possible changes (which may be considered as molecular), that the experiments with the ray of light were made (2723. 2729.), and also that in these and other experiments instituted for the purpose, a polarized ray was employed as the examiner; but the results were always negative, when by repetition and care sources of error were removed.

2752. The great differences in the degree of diamagnetic susceptibility and condition which the gases employed in the foregoing experiments possess or can assume, are such as to make one ready to suppose, that if they show no tendency in any case

to change in volume under the action of the magnet, so neither would any other gas or vapour do so, but that all the individuals belonging to this great class of bodies would be alike in that respect. In connection with this conclusion I may state, that I have on former occasions, and more lately, endeavoured to ascertain, by the use of very delicate apparatus and powerful electro-magnets, whether any change was produced in the volume of such fluids as water, alcohol and solution of sulphate of iron, but could observe no effect of the kind, and I do not believe in its existence. Still more recently, and in reference to the class of solid bodies, I have submitted iron as a magnetic metal, and bismuth as a diamagnetic body, to the same examination; the metals were employed both in the state of solid cylinders and of filings or fragments. The cylinders were put into glass tubes and the particles into glass bottles; gauges, like those described (2732.), were applied to them, and that part of the containing vessel which was not filled with metal, was occupied, in one set of experiments, by air, and in another by alcohol, yet in no case could the least change in the volume of the iron or bismuth be observed, however powerful the magnetic force to which they were submitted.

2753. One other result of a repulsive force seemed possible even in cases when, according to a former supposition (2751.), the tendency to expand equatorially might be compensated by an equal amount of tendency to contract in the axial direction, namely, that of the production of currents outwards or equatorially, *i. e.* in lines perpendicular to the magnetic axis, where pointed poles or the hour-glass core, already described, were used, and of other currents setting in towards that line along the inclined surfaces of the polar terminations; in some degree like those occurring so powerfully, and traced so readily when flame or hot air is observed in air, or when a stream of one gas is observed in another gas*.

2754. When however the gas occupying the whole of the magnetic field was uniform in nature and alike in temperature, not the slightest trace of such currents as these could be observed. It is not easy to devise unexceptionable tests of such motions, because visible bodies introduced into such a magnetic field to test the movements of the air there, are themselves diamagnetic; and if they form a little isolated cloud, are moved together and away as a diamagnetic body would be; but when the whole field was occupied pretty equally by very light particles of dust or lycopodium, and the magnet in powerful action, no signs of currents in the air were visible. Further, when a faint stream of diffuse cold smoke from a taper spark† was allowed to fall or rise a little on one side of the axial line, it was determined outwards and equatorially; but though it went outwards with the most force when equidistant from the two conical poles, or their representative parts in the double iron core (2738.), still when it was made to pass near to one side, it continued to go outwards and equatorially, even when, from its close vicinity to the iron surface, it had as it were to move

* Philosophical Magazine, 1847, vol. xxxi. pp. 402, 404, 409. † Ibid, p. 403.

over it; showing that the tendency of the smoke was outwards in *every part* of the magnetic field occupied by air or gas, and that therefore its motion was due to the action of the magnet on it as a diamagnetic, and not to currents of the air, which, if existing, would be inwards in one place or direction, and outwards in another.

2755. When magnetic or diamagnetic fluids were subject to the magnetic force upon a plate of mica over the poles, according to the ingenious arrangement of PLÜCKER, they quickly assumed the different forms correspondent to their nature, but after that there was no further motion or current in them. The cases are no doubt different to those where the whole of the magnetic field is occupied by the same medium; still, as far as it goes, it helps to confirm the conclusion that no currents are formed. On putting the same liquids between the poles in glass cells, no magnetic currents could be observed in them, though fine particles were introduced into the fluids, for the purpose of making such changes of place visible, if they occurred.

2756. So there is no evidence, either by the action on a ray of light (2727. 2729.), or by any expansion or contraction (2750.), or by the production of any currents (2754.), that the magnet exerts any direct power of attraction or repulsion on the particles of the different gases tried, or that they move in the magnetic field, as they are known to do, by any such immediate attraction or repulsion.

¶ ii. *Differential magnetic action.*

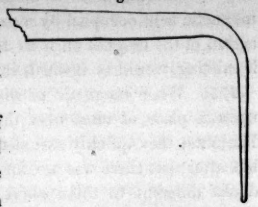
2757. Then what is the cause of the diamagnetic change of place? The effect is evidently a differential result, depending upon the *differences* of the two portions or masses of matter occupying the magnetic field, as the air and the streams of other gas in it*, or mercury and the tube of air in it (2407.), or water and the piece of bismuth in it (2301.); and though exhibited only in the action of masses, the latter must no doubt owe their differences to the qualities of the particles composing them. Yet it is to be observed, that no attempt to separate the perfectly mixed particles of very different substances has ever succeeded, though made with most powerful magnets. Oxygen and nitrogen differ exceedingly, yet no appearance of the least degree of separation occurred in very powerful magnetic fields†. In other experiments I have enclosed a dilute solution of sulphate of iron in a tube, and placed the lower end of the tube between the poles of a powerful horseshoe magnet for days together, in a place of perfectly uniform temperature, and yet without the least appearance of any concentration of the solution in that end which might indicate a tendency in the particles to separate.

2758. The diamagnetic phenomena of the gases, when considered as the differential result of the action of volumes of these bodies, may be produced and examined in a very useful manner by the employment of soap-bubbles, as follows:—A glass tube was fitted with a cap, stopcock and bladder, so that any given gas contained in the blad-

* Philosophical Magazine, 1847, vol. xxxi. p. 409. † Ibid. p. 416.

der might be sent through it, and also with a foot or stand so that it might be placed in any required position. The end of the tube was drawn down, bent at right angles, and cut off straight across at the extremity, being of the size and shape represented in fig. 4.

Fig. 4.



2759. It is easy to blow soap-bubbles at the end of such a tube, of any size up to an inch in diameter, and retain them for the time required by the action of the stopcock. The soapy water should be prepared, when wanted (and not beforehand), by putting a cutting or two of soap into a little cold distilled water, for then bubbles of the thinnest and most equable texture can be blown, which are more mobile than if thicker suds be used, and if a little care be taken, quite permanent enough for every useful experiment. The end of the pipe should be perfectly clean and free from heterogeneous matter (which is often destructive of the bubble), and should be wetted both inside and outside with the soap-water, and *left awhile in it before use.*

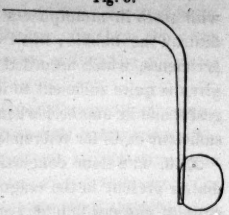
2760. If a bubble be blown with the end of the tube downwards, and be half an inch in diameter, it will usually have a little extra water at the bottom, and will hang from the slender extremity of the tube by an attachment so small as to allow it great freedom of motion. Hence it will swing to and fro like a pendulum; and according as there is more or less water at the bottom, it will vibrate more or less rapidly, will, as a whole, gravitate more or less powerfully, and therefore will retain its perpendicularly dependent position with more or less stability,—circumstances which are very useful in the employment of the bubble as a magnetic or diamagnetic indicator.

2761. The determination of the relative quantity of water which is in or upon the bubble is easily obtained within certain limits. If, after the pipe is dipped in the soap-water, the end be touched with a piece of wood or glass rod, which has also been kept in the soap-water, more or less of the liquid may be removed; and by observing the height at which the fluid stands by capillary action within the tube, which may be varied between $\frac{1}{10}$th and $\frac{1}{2}$ an inch, it is easy, after a few experimental trials, to observe how much is required to make a bubble charged with a certain amount of water, and how little to give a bubble without any dependent water below; and then it is just as easy, by arranging the amount of water beforehand, to blow a bubble of any required character. Even when no drop of water is left at the bottom, still a range of thickness or thinness in the film itself can be obtained.

2762. As the bubbles contain less and less of water, so are they rendered more sensitive in their action. They vibrate slower, and are more easily moved by forces applied laterally to them. The diamagnetic effect of the soap-water constituting them is less, and therefore that of the gas contained within them comparatively greater. If the bubble is very thin, the dependent position becomes a position of unstable equilibrium, for any inclination of the tube, or any lateral force, however small, then causes the bubble to pass to one side, and to run up and adhere to the

side of the tube, fig. 5. The dependent position supplies, in inclosed spaces or atmospheres, an exceedingly delicate indicator; and even when the bubble is on the side of the tube it still forms a very valuable instrument, for it freely moves round the tube as axis; and as it possesses a certain degree of steadiness, it can be held in the magnetic field in any position, and by its motion to or from the axial line, shows very well the magnetic or diamagnetic condition of the gas contained in it in relation to the surrounding air.

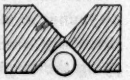
Fig. 5.



2763. If the mouth of the tube be turned upwards, bubbles of the thinnest texture can be blown; but they are then also very unstable in position, and run to the side of the tube; they can be used as indicators, as above (2762.). If the mouth of the tube be made broader, the bubbles, being thin, can be retained standing on the extremity; but as their attachment is larger, so they require more force to move them sideways, and they lose in delicacy of indication.

2764. It is convenient, in working with such bubbles, to make them nearly equal in size and thickness for the same set of comparative experiments. I usually employ them about half an inch in diameter. On blowing such a bubble with *air*, in the dependent position, placing it in the angle of the double pole on a level with the axial line (fig. 6), and then putting on the magnetic power, by the use of twenty pair of plates the bubble was deflected outwards from the axial line (or equatorially) with a certain amount of force, and returned to its first position on the interruption of the electric current. The deflection was not great, and being due to the water of the bubble, gave an indication of the amount of that effect, to be used as a correction in experiments with other gases.

Fig. 6.



2765. *Nitrogen in air.*—A bubble of nitrogen went outwards or equatorially in common air with a force much surpassing the outward tendency of a bubble of air (2764.), in a very striking and illustrative manner. It was often driven up from the end to the side of the tube; and when on the side, if presented inwards, it was driven to the outside of the tube, and however the tube was turned round, kept that position as long as the magnetic force was maintained. This effect is the more striking when it is considered that four-fifths of the air itself is nitrogen gas.

2766. *Oxygen in air.*—The effect was very impressive, the bubble being pulled inwards or towards the axial line sharply and suddenly, exactly as if the oxygen were highly magnetic. The result was expected, being in accordance with the phenomena presented by oxygen and nitrogen in a former investigation of the diamagnetic phenomena of the gases*.

2767. *Nitrous oxide and olefiant gases in air.*—The bubbles went outwards or diamagnetically with a force much greater than that due to the effect of the water of the bubble, proving the relation of these gases to air, and according with the results formerly obtained with streams of these substances†.

* Philosophical Magazine, 1847, vol. xxxi. pp. 410, 415.

† Ibid. p. 411.

2768. There is no difficulty in applying this method of observation to experiments with gases in atmospheres of other gases than air, provided they be such as do not destroy the bubble; but I do not consume time by detailing the results of such experiments, which accorded perfectly with those before obtained*. The description given is quite sufficient to illustrate the point stated, namely, that the motions of the gases, one in another, when in the magnetic field, is a differential result, and supply sufficient cases for reference hereafter.

2769. The same conclusion, that the effect is a differential result of the masses of matter present in the magnetic field, is also manifest from the consideration of the cases of gaseous, liquid, and solid diamagnetic bodies, advanced in a former part of these Researches (2405–14.); and a conclusion of the same kind, as regards magnetic bodies, may also be drawn from experiments then described (2361–68.).

¶ iii. *Magnetic characters of Oxygen, Nitrogen and Space.*

2770. The differential action of two portions of gas, or of any two bodies, may, by a more elaborate method, be examined in a manner far more interesting and important than that just described. The mode of action referred to may even be made the basis of instruments, by which, probably, most important indications and measurements of both magnetic and diamagnetic actions may be obtained, leading to results which are not even as yet contemplated by the imagination.

2771. If two portions of matter, gaseous or liquid, are tied together and placed in a symmetric magnetic field, on opposite sides of the magnetic axis, they will be simultaneously affected. If both are diamagnetic, or less magnetic than the medium occupying the magnetic field, both will tend to go outwards or equatorially; equally if they are alike, but unequally if they differ. The consequence will be, that, if they are placed, in the first instance, equidistant from the magnetic axis, the supervention of the magnetic force will not alter their position, provided they be alike; but if they differ, then their position will be changed; for the most diamagnetic will move outwards equatorially, pulling the least diamagnetic inwards until the two are in such new positions that the forces acting on them are equipoised, and they will assume a position of stable equilibrium. Now the distance through which they will move may be used indirectly, or better still, the force required to restore them to their equidistant position may be employed directly to estimate the tendency each had to go from the magnetic axis; that is, to give their relative diamagnetic intensities.

2772. That I might submit gases to such a method of examination, I selected a piece of very thin and regular flint-glass tube, about $\frac{5}{16}$ths of an inch external diameter, and not more than $\frac{1}{60}$th of an inch in thickness, and drawing at the blowpipe lamp two equable portions of this tube into the shape and size represented, fig. 7, in which the barrel part is $1\frac{1}{2}$ inch long, I filled one with oxygen gas and the other

Fig. 7.

* Philosophical Magazine, 1847, vol. xxxi. pp. 414, 415.

with nitrogen gas, and then sealed them up hermetically. The end of the prolonged part of each was touched whilst warm with sealing-wax and a thread fastened to it, which thread was tied into a loop, also represented of full size. By these the tubes were to be suspended perpendicularly from a torsion balance, so that the middle of each should, when in place, be on a level with the magnetic axis.

2773. The torsion balance consisted of a bundle of sixty equally stretched cocoon silk fibres, made fast above to a vertical axis carrying a horizontal index and graduated plate, and below to a horizontal lever. A cross bar, about $1\frac{1}{2}$ inch long, was attached to one end of this lever, also in the horizontal plane; and on the extremities of this cross bar, and $8\frac{1}{2}$ inches from the centre of motion, were hung the two tubes of oxygen and nitrogen (2772.), counterbalanced by a weight on the other arm of the horizontal level. The whole was thus so placed and adjusted in relation to the electro-magnet, furnished at the time with the double cone core or keeper (2764.), that the middle part of each tube was level with the middle of the core, and equidistant on each side from it. Under these circumstances, if any motion was given to the balance, so as to make its arm vibrate, the vibrations were made with great slowness, in consequence of the weight of the whole moving arrangement, and the small amount of torsion force in the cocoon silk.

2774. The moment the magnetic force was thrown into action all things changed. The oxygen tube was immediately carried inwards towards the axis, and the nitrogen tube driven outwards on the contrary side. The balance swung beyond its new place of rest and then returned with considerable power, vibrating many times in the period, which before was filled by a single oscillation; and when it had come to its place of rest, or of stable equilibrium, the oxygen tube was about one-eighth of an inch from the iron of the core, and the nitrogen tube four-eighths distant. Ten revolutions of the torsion axis altered only in a slight degree these relative distances.

2775. The actions which determine the mutual self-adjustment of the oxygen and nitrogen, as regards their place in relation to the magnetic axis, are very simple and evident. In the first place, the *glass* of the tubes is more diamagnetic than the surrounding medium or air (2424.), and therefore each tends to move outwards; but being equal in nature and condition to each other, they tend to move with equal force when at equal distances, and at those distances compensate each other. If one be driven inwards, it is subjected to a greater exertion of force by coming into a more intense part of the magnetic field; and the other, being at the same time carried outwards, is for a corresponding reason in a place of less intense action; and therefore, as soon as the constraint is removed, the system returns to its position of stable equilibrium, in which the two bodies are equidistant from the magnetic axis.

2776. The *contents* also of the tubes are subject to the magnetic forces, and as the result shows (2774.), in very different degrees. Either the oxygen tends inwards much more forcibly than the nitrogen, or the nitrogen tends outwards more powerfully than the oxygen; and the difference must exist to a very great degree, for it is such as to carry the glass of the oxygen tube up to a position so near the axis that it

could not by itself, or with mere air inside, retain it for a moment without the aid of considerable restraint. The power with which the tubes only would retain their equidistant position, combined with the extent to which they are displaced from this position, shows the great amount of force which this conjoint action of the oxygen and the nitrogen leaves free to be exerted in the one direction, namely, from the oxygen inwards or axially, for though the action be complicated the result is simple. By former experiments, the nitrogen is known to pass equatorially and the oxygen axially in air*, and the nitrogen tube will pass equatorially according to a certain differential force, depending on the flint-glass and the nitrogen on the one hand, and the bulk of air displaced by them on the other. The oxygen tube in like manner will tend to pass axially by a differential force, the amount of which will depend upon the tendency of the oxygen to go axially, of its tube to go equatorially, and of their joint relation to the air they displace. But both the tubes and their contents are by their joint relation to the air and their mechanical connexion so related to each other, that when a force (as of torsion) is employed to restore them to their equidistant position from the magnetic axis, all consideration of the matter of the tubes and of the air as a surrounding medium may be dismissed. The gases within them may be considered as in immediate relation with each other and the magnetic axis, and disembarrassed from all other actions: and the force which may be found needful to place them *equidistant*, is the measure of their magnetic or diamagnetic differences.

2777. Having thus explained the general principles of action, I will not at present go into their application in the construction of a measuring instrument or the results obtained with it, further than is required for the general elucidation of magnetic and diamagnetic bodies, and the determination of the true zero-point (2721. 2722.).

2778. The principles just described enabled me to return to a method of investigation which on a former occasion greatly excited my hopes (2433.), but which seemed then suddenly cut off by want of power. Various bodies, whether considered as magnetic or diamagnetic substances, admit of two modes of treatment, which promise to be exceedingly instructive as regards their properties and their destined purposes in natural operation. A gas may be *heated* or *cooled*, and the effect of temperature, which is known to be very influential†, may now be ascertained without any change in the bulk of the gas; or it may be *rarefied* and *condensed* through a very extensive range, and the effect of this kind of change upon it ascertained independent of temperature or the presence of any other substance. Solids and liquids do not admit of these methods of examination, and do not therefore assist in the determination of the zero-point and of the true distinction of magnetic and diamagnetic bodies in the same manner that the gases do.

2779. It appeared to me that if a gaseous body were magnetic, then its magnetic properties ought to be diminished in proportion as it was rarefied, *i. e.* that equal volumes of such a gas at different pressures ought to be more magnetic, as they are denser; on the other hand, that if a gas were diamagnetic, rarefaction ought to

* Philosophical Magazine, 1847, vol. xxxi. p. 409.

† Ibid. pp. 406, 417.

diminish its diamagnetic character, until, when reduced to the condition of a vacuum, it should disappear. In other words, if two opposed portions of the same magnetic gas, one rarer than the other, were subjected at once to the magnetic force, the *denser* ought to approach the axial line, or be drawn into the place of most intense action; whereas if two similarly opposed portions of a diamagnetic gas were subjected to the magnetic action, the more expanded or *rarer* gas ought to go inwards to the place of strongest action.

2780. Several bulbs of oxygen (fig. 8), similar in arrangement to those already described (2772.), and very nearly alike in size, were prepared and hermetically sealed, after that the quantity of gas within them had been reduced to a certain degree by the air-pump. The first contained the gas at the pressure of one atmosphere; the second had the gas at half an atmosphere, or 15 inches of mercury; the third contained gas at the pressure of 10 inches of mercury; and the fourth, after being filled with oxygen, was reduced to as good a vacuum as an excellent air-pump could effect. When the first of these was compared with the other three, the effect was most striking; opposed to the half atmosphere, it went towards the axis, driving the expanded portion away; when in relation to the one-third atmosphere, it went inwards or axially with still more power; and when opposed to the oxygen vacuum, it took its place as close to the iron core as in the former case, when contrasted with nitrogen (2774.); and it was manifest that the diamagnetic power of the glass tube which inclosed it (2775.), was the only thing which prevented the oxygen from pressing against the iron core occupying the centre of the magnetic field.

Fig. 8.

2781. On experimenting with the other tubes exactly the same result was obtained. Thus the tube with one-third of an atmosphere, in association with the vacuum tube, went inwards, driving the other outwards, *i. e.* it was more magnetic than the vacuum; but in association with the one-half atmosphere tube it went outwards, whilst the denser gas passed inwards. Any one of the tubes, if associated with another having a rarer atmosphere, passed inwards or magnetically, whilst if associated with others having denser atmospheres it passed outwards, being driven off by the superior magnetic force of the denser gas. As far as I could ascertain in these preliminary forms of experiment, the tendency inwards or axially appeared to be in proportion to the density of the gas; but the exact measurement of these forces will be given hereafter.

2782. Thus oxygen appears to be a very magnetic substance, for it passes axially, or from weaker to stronger places of force, with considerable power; a conclusion in accordance with the result of former observations*. Moreover it passes more powerfully when dense than when rare, its tendency inwards being apparently in proportion to its density. Hence, as the oxygen is removed, the magnetic force disappears with it, until when a vacuum is obtained, little or no trace of attraction or inward force remains. No doubt it may be said that dense oxygen is less diamagnetic than

* Philosophical Magazine, 1847, vol. xxxi. pp. 410, 415.

rare oxygen, or a vacuum. This however would imply, that the acting force of a substance, as the oxygen, could increase in proportion as the quantity of the substance diminished, which is not, I think, a philosophical assumption; and besides that, other reasons will soon appear to show that the magnetic condition which disappears as the oxygen is removed, belongs to, and is dependent upon that substance, and that oxygen is therefore a truly magnetic body.

2783. *Nitrogen*, being the other and larger part of the atmosphere, was then subjected to experiment, and three tubes, one containing the gas at a pressure of 30 inches of mercury, another with the gas at the pressure of 15 inches, and the third reduced as nearly as it could be to a vacuum, were prepared (2780.). When these were compared one with another in the magnetic field, they were found to be so nearly alike as not to be distinguishable from each other, *i. e.* they remained equidistant from the magnetic axis. I do not mean to imply that nitrogen at these different pressures is absolutely the same bulk for bulk (an instrument now under construction will enable me hereafter to compare and measure with infinitely greater accuracy, and to ascertain these points); but as compared with oxygen, the great and extraordinary differences produced by rarefaction there, have no corresponding differences here. If there are any, they are insensible at present, and may, for the chief purpose of this paper and the determination of the zero-point between magnetics and diamagnetics, be taken as nothing.

2784. Nitrogen therefore appears to be neither magnetic nor diamagnetic; if it were either, it could not but fall in its specific condition as it was rarefied; as it is, it is equivalent to a vacuum. If a given space be considered as a vacuum, into which oxygen or nitrogen is to be gradually introduced, as oxygen is added the space becomes more and more magnetic, *i. e.* more competent to admit of the kind of action distinguished by that word; but the corresponding gradual addition of nitrogen to an empty space produces no effect of that kind, or the contrary, and the nitrogen is therefore neither magnetic nor diamagnetic, but like space itself.

2785. As yet I have found no gas, which, being on the diamagnetic side of zero, can at all compare with oxygen in the range of effect produced by rarefaction. For the present, I may mention olefiant gas and cyanogen as substances which appear to proceed inwards, or towards the axial line, as they are more rarefied. They are therefore not merely at zero, but are in opposition to oxygen and are diamagnetic bodies. But if we want a body that is strongly and undeniably diamagnetic, and which, being added to or introduced into space, will make it diamagnetic, as oxygen renders it magnetic, then flint glass or phosphorus presents us with such a substance. When these bodies are made into forms similar to the volumes of nitrogen, or the vacua in size and shape, and are compared with them on the torsion balance, they pass outwards with much force; and it is probably the great diamagnetic force of the glass of the tubes that prevents the effect of rarefaction from being more evident in olefiant and other gases.

2786. When a tube has been filled with a particular gas, then exhausted as much

as possible, and sealed up hermetically, it may be considered as inclosing what is commonly called a vacuum. I have prepared many such vacua, and may be permitted to distinguish them by the name of the gas, traces of which still remain. In comparing these vacua in the magnetic field (2773.), they appeared to me to be in all respects alike; the oxygen vacuum was not more magnetic than the hydrogen, nitrogen, or olefiant vacuum. Their differences, if any, were far smaller than the differences which could be produced by the variations of size and other conditions of the glass bulbs, and can only be made manifest by the means hereafter to be used (2783.); and I am fully persuaded that they will ultimately be nearly alike, ranging close *up to and about a perfect* vacuum.

2787. Before determining the place of zero amongst magnetic and diamagnetic bodies, we have to consider the true character and relation of *space* free from any material substance. Though one cannot procure a space perfectly free from matter, one can make a close approximation to it in a carefully prepared Torricellian vacuum. Perhaps it is hardly necessary for me to state, that I find both iron and bismuth in such vacua perfectly obedient to the magnet. From such experiments, and also from general observations and knowledge, it seems manifest that the lines of magnetic force (2149.) can traverse pure space, just as gravitating force does, and as static electrical forces do (1616.); and therefore space has a magnetic relation of its own, and one that we shall probably find hereafter to be of the utmost importance in natural phenomena. But this character of space is not of the same kind as that which, in relation to matter, we endeavour to express by the terms magnetic and diamagnetic. To confuse them together would be to confound space with matter, and to trouble all the conceptions by which we endeavour to understand and work out a progressively clearer view of the mode of action and laws of natural forces. It would be as if, in gravitation or electric forces (1613.), one were to confound the particles acting on each other with the space across which they are acting, and would, I think, shut the door to advancement. Mere space cannot act as matter acts, even though the utmost latitude be allowed to the hypothesis of an ether; and admitting that hypothesis, it would be a large additional assumption to suppose that the lines of magnetic force are vibrations carried on by it (2591.); whilst as yet, we have no proof or indication that time is required for their propagation, or in what respect they may in general character assimilate to, or differ from, the respective lines of gravitating, luminiferous, or electric forces.

2788. Neither can space be supposed to have those circular currents round points diffused through it, which AMPÈRE's theory assumes to exist around the particles of ordinary magnetic matter, and which I had for a moment supposed might exist in the contrary direction round the particles of diamagnetic matter (2429. 2640. &c.). The imagination, restrained by philosophical considerations, fails to find anything in pure space about which the currents could circulate, or to which they could by any association be attached; and the difficulty, if already not immeasurable, would be

still greater to those, if there be any, who, assuming that magnetic and diamagnetic bodies are alike in nature, must assume that there are like currents in both; for it does not seem possible to add (for instance) phosphorus having such a magnetic constitution to space, supposed to be of a similar constitution, and yet to have as a result a diminution of the magnetic powers of the space.

2789. As space therefore comports itself independently of matter, and after another manner, the different varieties of matter must, in relation to their respective qualities, be considered amongst themselves. Those which produce no effect when added to space, appear to me to be neutral or to stand at zero. Those which bring with them an effect of one kind will be on the one side of zero, and those which produce an effect of the contrary kind will be on the other side of zero; by this division they constitute the two subdivisions of magnetic and diamagnetic bodies. The law which I formerly ventured to give (2267. 2418.), still expresses accurately their relations; for in an absolute vacuum or free space, a magnetic body tends from weaker to stronger places of magnetic action, and a diamagnetic body under similar conditions from stronger to weaker places of action.

2790. Now that the *true zero* is obtained, and the great variety of material substances satisfactorily divided into two general classes, it appears to me that we want another name for the magnetic class, that we may avoid confusion. The word *magnetic* ought to be general, and include *all* the phenomena and effects produced by the power. But then a word for the subdivision, opposed to the diamagnetic class, is necessary. As the language of this branch of science may soon require general and careful changes, I, assisted by a kind friend, have thought that a word not selected with particular care might be provisionally useful; and as the magnetism of iron, nickel and cobalt, when in the magnetic field, is like that of the earth as a whole, so that when rendered active they place themselves parallel to its axis or lines of magnetic force, I have supposed that they and their similars (including oxygen now) might be called paramagnetic bodies, giving the following division:—

$$\text{Magnetic}\begin{cases}\text{Paramagnetic.}\\ \text{Diamagnetic.}\end{cases}$$

If the attempt to facilitate expression be not accepted, I hope it will be excused.

2791. From the presence of oxygen in the air, the latter is, as a whole, a magnetic medium of no small power. Hence all the comparative experiments on the diamagnetic condition of other gases, made by passing streams of them through it and through each other*, require a correction, which occasionally may place some of these bodies on the paramagnetic side of zero. Even solid and fluid substances may be thus affected; and the preliminary list, which I formerly gave (2424.), will need alteration in this respect. I hope soon however to have the means of ascertaining,

* Philosophical Magazine, 1847, vol. xxxi. pp. 407, 420, &c. &c.

not only the place of bodies, but also their relative degrees of force, at the same and at different temperatures, with a degree of accuracy that will serve great purposes in the further development of this branch of science.

2792. Amongst the gases hitherto examined there is nothing that compares with oxygen. The following are comparatively indifferent by the side of it:—chlorine and bromine vapour, cyanogen, nitrogen, hydrogen, carbonic acid, carbonic oxide, olefiant gas, nitrous oxide, nitric oxide, nitrous acid vapour, muriatic acid, sulphurous acid, hydriodic acid, ammonia, sulphuretted hydrogen, coal-gas, ether vapour and sulphuret of carbon vapour; for though some, as olefiant and cyanogen gases, appear to be a little diamagnetic, and others, as nitrous oxide and nitric oxide, are magnetic, yet their effects disappear in comparison with the results produced by oxygen.

2793. I hope to give the correct expression of the paramagnetic force of oxygen (2783.) hereafter, in the meantime I am tempted to give one or two rough illustrations of its degree in this place, in addition to the former one (2774.). The capacity of the oxygen bulb, containing one atmosphere, is not quite 0·34 of a cubic inch, and the weight therefore of the oxygen within 0·117 of a grain. I endeavoured to compare this quantity in the first place with soft iron, and therefore attached a portion of that metal, having one-tenth of this weight or 0·012 of a grain, to a fine platina wire fixed into one end of a vessel, corresponding in size to that containing the oxygen, so as to bring the iron into the middle, and then the bulb was exhausted and hermetically sealed. Being now opposed to the oxygen tube in the magnetic field, it was found, as expected, far to surpass the oxygen in magnetic power. As it was inconvenient further to reduce the iron or to enlarge the oxygen, another magnetic substance was employed for the comparison.

2794. One hundred grains of clean, good, crystallized protosulphate of iron were dissolved in distilled water, and diluted until a glass bulb, of nearly the same size as the oxygen bulb when filled with the solution, was equal to the oxygen bulb in force, and stood equidistant from the axial line, as far as I could judge by the present modes of observation. When the solution had this strength, it occupied the bulk of 17½ cubic inches. As the bulk of the oxygen is only 0·34 of a cubic inch (2793.), that volume of this solution would contain very nearly two grains of crystallized sulphate of iron, equivalent to 0·4 of a grain of metallic iron; so that, bulk for bulk, oxygen is equally magnetic with a solution of sulphate of iron in water containing seventeen times the weight of the oxygen in crystallized protosulphate of iron, or 3·4 times its weight of metallic iron in that state of combination.

2795. Again, the oxygen tubes, containing respectively one atmosphere and a vacuum (2780.), were adjusted about an inch apart, and placed on each side of the magnetic axis, and the force of the magnet developed. The oxygen of course approached the magnetic axis, and the vacuum passed equatorially. A slender glass filament, about 6 inches in length, had been drawn out at the lamp and fixed to a foot; and the end of this filament was then employed to press back the oxygen tube into its

original place, and render it equidistant from the magnetic axis with the vacuum tube. In this position the two tubes would, as respects the glass, neutralize each other (2775.); and considering the vacuum as zero, the oxygen alone may be considered as active, and the force required to hold it out may be looked upon as the force with which the oxygen, at that distance of half an inch, tended to go to the magnetic axis. The deflection of the glass filament or spring, at the place where the oxygen tube was held by it, was rather more than 1 inch from its position when relieved from the pressure of the tube. Being taken away, it was set up in the horizontal position (after being turned 90° on its axis, so that the flexure might be in the same direction, relative to the filament, as before); and the position of the end being marked, weights were put on it at the place of former contact with the oxygen tube, until they produced the same amount of deflection as before. It required rather more than the tenth of a grain to produce this effect; and this, considering that the whole oxygen only weighed 0·117 of a grain, and that no part of it was nearer than half an inch, whilst the average distance of the mass was above an inch from the magnetic axis, gives a high expression for the magnetic power.

2796. It is hardly necessary for me to say here that this oxygen cannot exist in the atmosphere, exerting such a remarkable and high amount of magnetic force, without having a most important influence on the disposition of the magnetism of the earth as a planet, especially if it be remembered that its magnetic condition is greatly altered by variations in its density (2781.) and by variations in its temperature*. I think I see here the real cause of many of the variations of that force, which have been, and are now, so carefully watched on different parts of the surface of the globe. The daily variation and the annual variation both seem likely to come under it; also very many of the irregular continual variations which the photographic process of record renders so beautifully manifest. If such expectations be confirmed, and the influence of the atmosphere be found able to produce results like these, then we shall probably find a new relation between the aurora borealis and the magnetism of the earth, namely, a relation established, more or less, through the air itself in connexion with the space above it; and even magnetic relations and variations which are not as yet suspected, may be suggested and rendered manifest and measurable, in the further development of what I will venture to call *Atmospheric Magnetism* (2847. &c.). I may be over-sanguine in these expectations, but as yet I am sustained in them by the apparent reality, simplicity and sufficiency of the cause assumed, as it at present appears to my mind. As soon as I have sufficiently submitted these views to a close consideration and the test of accordance with observation, and where applicable with experiments also, I will do myself the honour to bring them before the Royal Society.

* Philosophical Magazine, 1847, vol. xxxi. p. 417.

Royal Institution, August 2, 1850.

III. *Experimental Researches in Electricity.—Twenty-sixth Series. By* MICHAEL FARADAY, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.*

Received October 9*,—Read November 28, 1850.

§ 32. *Magnetic conducting power.* § 33. *Atmospheric magnetism.*

¶ i. *Magnetic conduction.* ¶ ii. *Conduction polarity.* ¶ iii. *Magnecrystallic conduction.* § 33. *Atmospheric magnetism.* ¶ i. *General Principles..*

¶ i. *Magnetic conduction.*

2797. THE remarkable results given in a former series of these researches (2757. &c.) respecting the powerful tendency of certain gaseous substances to proceed either to or from the central line of magnetic force, according to their relation to other substances present at the same time, and yet the absence of all condensation or expansion of these bodies (2756.) which might be supposed to be consequent on such an amount of attractive or repulsive force as would be thought needful to produce this tendency and determination to particular places, have, upon consideration, led me to the idea, that if bodies possess different degrees of *conducting power* for magnetism, that difference may account for all the phenomena; and, further, that if such an idea be considered, it may assist in developing the nature of magnetic force. I shall therefore venture to think and speak freely on this matter for a while, for the purpose of drawing others into a consideration of the subject; though I run the risk, in doing so, of falling into error through imperfect experiments and reasoning. As yet, however, I only state the case hypothetically, and use the phrase *conducting power* as a general expression of the capability which bodies may possess of affecting the transmission of magnetic force; implying nothing as to how the process of conduction is carried on. Thus limited in sense, the phrase may be very useful, enabling us to take, for a time, a connected, consistent and general view of a large class of phenomena; may serve as a standard of meaning amongst them, and yet need not necessarily involve any error, inasmuch as whatever may be the principles and condition of conduction, the phenomena dependent on it must consist among themselves.

2798. If a medium having a certain conducting power occupy the magnetic field, and then a portion of another medium or substance be placed in the field having

* Revised by the author and returned by him November 12, 1850.

a greater conducting power, the latter will tend to draw up towards the place of greatest force, displacing the former. Such at least is the case with bodies that are freely magnetic, as iron, nickel, cobalt and their combinations (2357. 2363. 2367. &c.), and such a result is in analogy with the phenomena produced by electric induction. If a portion of still higher conducting power be brought into play, it will approach the axial line and displace that which had just gone there; so that a body having a certain amount of conducting power, will appear as if attracted in a medium of weaker power, and as if repelled in a medium of stronger power by this differential kind of action (2367. 2414.).

2799. At the same time that this idea of conduction will thus account for the place which a given substance would take up, as of oxygen in the axial line if in nitrogen, or of nitrogen at a distance if in oxygen, it also harmonizes with the fact, that there are no currents induced in a single gas occupying the magnetic field (2754.), for any one particle can then conduct as well as any other, and therefore will keep its place; and it also agrees, I think, with the unchangeability of volume (2750.).

2800. In reference to the latter point, we have to consider that the force which urges such a body as oxygen towards the middle of the field, is not a central force like gravitation, or the mutual attraction of a set of particles for each other; but an axial force, which, being very different in character in the direction of the axis and of the radii, may, and must produce its effect in a very different manner to a purely central force. That these differences exist, is manifest by the action of transparent bodies, when in the magnetic field, upon a ray of light; and also by the ordinary action of magnetic bodies: and hence, perhaps, the reason, that when oxygen is drawn into the middle of the field, in consequence of its conducting power, still its particles are not compressed together (2721.) by a force that otherwise would seem equal to that effect (2766.).

2801. So when two separate portions of oxygen or nitrogen are in the magnetic field, the one passes inwards and the other outwards, without any contraction or expansion of their relative volumes; and the result is differential, the two bodies being in *relation to and dependence on* each other, by being simultaneously related to the lines of magnetic force which pass conjointly through them both, or through them, and the medium in which they are conjointly immersed.

2802. I have already said, in reference to the transference onwards of magnetic force (2787.), that pure space or a vacuum permits that transference, independent of any function that can be considered as of the same nature as the conducting power of matter; and in a manner more analogous to that in which the lines of gravitating force, or of static electric force, pass across mere space. Then as respects those bodies which, like oxygen, facilitate the transmission of this power more or less, they class together as magnetic or paramagnetic substances (2790.); and those bodies, which, like olefiant gas or phosphorus, give more or less obstruction, may be arranged together as the diamagnetic class. Perhaps it is not correct to express both these

qualities by the term *conduction*; but in the present state of the subject, and under the reservation already made (2797.), the phrase may I think be employed conveniently without introducing confusion.

2803. If such be a correct general view of the nature and differences of paramagnetic and diamagnetic substances, then the internal processes by which they perform their functions can hardly be the same, though they might be similar. Thus they *may* have circular electric currents in opposite directions, but their distinction can scarcely be supposed to depend upon the difference of force of currents in the *same* direction. If the view be correct also, though the results obtained when two bodies are simultaneously present in the magnetic field may be considered as differential (2770. 2768.) even though one of them be the general medium, yet the consequence of the presence of conducting power in matter renders a *single* body, when in space, subject to the magnetic force; and the result is, that when a paramagnetic substance is in a magnetic field of unequal force, it tends to proceed from weaker to stronger places of action, or is *attracted*; and when a diamagnetic body is similarly circumstanced, it tends to go from stronger to weaker places of action, or is *repelled* (2756.).

2804. Matter, when its powers are under consideration, may, as to its quantity, be considered either by weight or by volume. In the present case, where the effects produced have an immediate reference to mere space (2787. 2802.), it seems proper that the volume should be considered as the representation, and that in comparing one substance with another, equal volumes should be employed to give correct results. No other method could be used with the differential system of observation (2772. 2780.).

2805. Some experimental evidence, other than those of change of situation, of the existence of this conducting power, by differences in which, I am endeavouring to account for the peculiar characteristics of paramagnetic and diamagnetic bodies, may well be expected. This evidence exists; but as certain considerations connected with polarity preclude me from calling too freely upon iron, cobalt, or nickel (2832.) for illustrations, and as in other bodies which are paramagnetic, as well as in those that are diamagnetic, the effects are very weak, they will be better comprehended after some further general consideration of the subject (2843.).

2806. I will now endeavour to consider what the influence is which paramagnetic and diamagnetic bodies, viewed as conductors (2797.), exert upon the lines of force in a magnetic field. Any portion of space traversed by lines of magnetic power, may be taken as such a field, and there is probably no space without them. The condition of the field may vary in intensity of power, from place to place, either along the lines or across them; but it will be better to assume for the present consideration a field of equal force throughout, and I have formerly described how this may, for a

certain limited space, be produced (2465.). In such a field the power does not vary either along or across the lines, but the distinction of direction is as great and important as ever, and has been already marked and expressed by the term axial and equatorial, according as it is either parallel or transverse to the magnetic axis.

2807. When a paramagnetic conductor, as for instance, a sphere of oxygen, is introduced into such a magnetic field, considered previously as free from matter, it will cause a concentration of the lines of force on and through it, so that the space occupied by it transmits more magnetic power than before (fig. 1). If, on the other hand, a sphere of diamagnetic matter be placed in a similar field, it will cause a divergence or opening out of the lines in the equatorial direction (fig. 2); and less magnetic power will be transmitted through the space it occupies than if it were away.

Fig. 1.

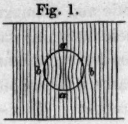
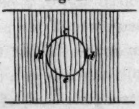


Fig. 2.



2808. In this manner these two bodies will be found to affect, *first* the *direction* of the lines of force, not only within the space occupied by themselves, but also in the neighbouring space, into which the lines passing through them are prolonged; and this change in the course of the lines will be in the contrary direction for the two cases.

2809. *Secondly*, they will affect the *amount* of force in any particular part of the space within or near them; for as every section across the line of such a magnetic field must be definite in amount of force, and be in that respect the same as every other section, so it is impossible to cause a concentration within the sphere of oxygen (fig. 1) without causing also a simultaneous concentration in the parts axially situated as *a a* outside of it, and a corresponding diminution in the parts equatorially placed, *b b*. On the other hand, the diamagnetic body (fig. 2) will cause diminution of the magnetic force in the parts of space axially placed in respect of it, *c c*, and concentration in the near equatorial parts, *d d*. If the magnetic field be considered as limited in its extent by the walls of iron forming the faces of opposed poles (2465.), then even the distribution of the magnetism within the iron itself will be affected by the presence of the paramagnetic or diamagnetic bodies; and this will happen to a very large extent indeed, when, from among the paramagnetic class, such substances as iron, nickel or cobalt are selected.

2810. The influence of this disturbance of the forces upon the place and position of either a paramagnetic or a diamagnetic body placed within the magnetic field, is readily deduced upon consideration and easily made manifest by experiment. A small sphere of iron placed within a field of equal magnetic power, bounded by the iron poles, has a position of unstable equilibrium, equidistant from the iron surfaces, and at such time a great concentration of force takes place through it, and at the iron faces opposite to it, and through the intervening axial spaces. If the sphere be on either side of the middle distance, it flies to the nearest iron surface, and then can determine the greatest amount of magnetic force to or upon the axial lines which pass through it.

2811. If the iron be a spheroid, then its greatest diameter points axially, whether it be in the position of unstable equilibrium, nearer to or in contact with the iron walls of the field. As the circumstances are now more favourable for the concentration of force in the axial line passing through the body than before, so this result can be produced by much weaker paramagnetics than iron, and I have no doubt could easily be produced by a vessel of oxygen or nitric oxide gas (2782. 2792.). It now becomes indeed a form, though not the best, of that experiment by which the magnetic condition of bodies is considered as most sensitively tested.

2812. The relative deficiency of power in diamagnetic bodies renders any attempt to obtain the converse phenomena to those of iron somewhat difficult; in order therefore to exalt the conditions, I used a saturated solution of protosulphate of iron in the magnetic field; by this means I strengthened the lines of power passing across it, without disturbing its equality in the parts employed, or introducing any error into the principle of the experiment, and then used bismuth as the diamagnetic body. A cylinder of this substance, suspended vertically, tended well towards the middle distance, finding its place of stable equilibrium in the spot where the paramagnetic body had unstable equilibrium. When the cylinder was suspended horizontally, then the direction it took was equatorial; and this effect also was very clear and distinct.

2813. These relative and reverse positions of paramagnetic and diamagnetic bodies, in a field of equal magnetic force, accord well with their known relations to each other, and with the kind of action already laid down in principle (2807.) as that which they exert on the magnetic power to which they are subjected. One may retain them in the mind by conceiving that if a liquid sphere of a paramagnetic conductor were in the place of action, and then the magnetic force developed, it would change in form and be prolonged axially, becoming an oblong spheroid; whereas if such a sphere of diamagnetic matter were placed there, it would be extended in the equatorial direction and become an oblate spheroid.

2814. The *mutual action* of two portions of paramagnetic matter, when they are both in such a field of equal magnetic force, may be anticipated from the principles (2807. 2830.), or from the corresponding facts, which are generally known. Two spheres of iron, if retained in the same equatorial plane, repel each other strongly; but as they are allowed to depart out of that plane, they first lose their mutual repulsive force and then attract each other, and that they do most powerfully when in an axial direction.

2815. With diamagnetic bodies the mutual action is more difficult to determine, because of the comparative lowness of their condition. I therefore resorted to the expedient, before described, of using a saturated solution of protosulphate of iron as the medium occupying the field of equal magnetic force, and employing two cylinders of phosphorus, about an inch long and half an inch in diameter, as the diamagnetic bodies. One of these was suspended at the end of a lever, which was itself suspended by cocoon-silk, so as to have extremely free motion, and the adjustments were such, that when the phosphorus cylinder was in the middle of the magnetic field, it was free

to move equatorially or across the lines of magnetic force; it however had *no tendency* to do so under the influence of the magnetic force. The other cylinder was attached to a copper wire handle, and could be placed in a fixed position on either side of the former cylinder; it was therefore adjusted close by the side of it, and the two retained together until all disturbance from motion of the fluid or of the air had ceased; then the retaining body was removed, the two phosphorus cylinders still keeping their places; finally, the magnetic power was brought into action, and immediately the moveable cylinder separated slowly from the fixed one and passed to a distance. If brought back again whilst the magnet was active, when left at liberty it receded; but if restored to close vicinity, when the magnetic force was away, it retained that situation. The effect took place either in the one direction or the other, according as the fixed cylinder was on this or that side of the moving one; but the motion was in both cases across the lines of magnetic force, and was indeed mechanically and purposely limited to that direction by the mode of suspension. When two bismuth balls were placed, in respect of each other, in the direction of the magnetic axis, so that one might move, but only in the direction of that axis, its place was not sensibly affected by the other; the tendency of the free one to go to the middle of the field (2812.) overpowered any other tendency that might really exist.

2816. Thus two diamagnetic bodies, when in the magnetic field, do truly affect each other; but the result is not opposed in its direction to that of paramagnetic bodies, being in both cases a separation of the substances from each other.

2817. The comparison of the action of para- and diamagnetic bodies on each other, was completed by using water as the medium in a field of equal magnetic force, and suspending a piece of phosphorus from the torsion balance. When the magnetic power was on, this phosphorus was repelled equatorially, as before, by another piece of phosphorus, but it was attracted by a tube filled with a saturated solution of proto-sulphate of iron; so paramagnetic and diamagnetic bodies attract each other equatorially in a mean medium, but each repels bodies of its own kind (2831.).

¶ ii. *Conduction polarity.*

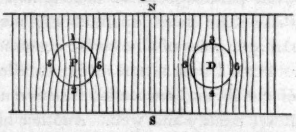
2818. Having thus considered briefly the effects which the disturbance of the lines of force, by the presence of paramagnetic and diamagnetic bodies, is competent to produce (2807. &c.), I will ask attention to that which may be considered as their polarity: not wishing by the term to indicate any internal condition of the substances or their particles, but the condition of the mass as a whole, in respect of the state into which it is brought by its own disturbance of the lines of magnetic force; and that, both in regard to its condition with respect to other bodies similarly affected; and also in regard to differences existing in different parts of its own mass. Such a condition concerns what may be called conduction polarity. Bodies in free space, when under magnetic action, will possess it in its simplest condition; but bodies immersed in other media will also possess it under more complicated forms, and its amount may then be varied, being reversed or increased, or diminished to a very large extent.

2819. Taking the simplest case of paramagnetic polarity, or that presented in fig. 1 (2807.), it consists in a convergence of the lines of magnetic force on to two opposed parts of the body, which are to each other in the direction of the magnetic axis. The difference in character of the two poles at these parts is very great, being that which is due to the known difference of quality in the two opposite directions of the line of magnetic force. Whether polar attraction or repulsion exists amongst paramagnetic bodies, when they present mere cases of conduction (as oxygen, for instance), is not yet certain (2827.), but it probably does; and if so, will doubtless be consistent with the attraction and repulsion of *magnets* having correspondent poles.

2820. When we consider the conduction polarity of a diamagnetic body, matters appear altogether different. It has not a polarity like that of a paramagnetic substance, or one the mere reverse (in name or direction of the lines of force) of such a substance, as I, WEBER and others have at times assumed (2640.), but a state of its own altogether special. Its polarity consists of a divergence of the lines of power on to, or a convergence from the parts, which being opposite, are in the direction of the magnetic axis; so that these poles, having the *same* general and opposite relations to each other, which correspond to the differences in the poles of paramagnetic bodies, have still, under the circumstances, that striking contrast and difference from the polarity of the latter bodies which is given by convergence and divergence of the lines of force.

2821. Let fig. 3 represent a limited magnetic field with a paramagnetic body P, and a diamagnetic body, D, in it, and let N and S represent the two walls of iron associated with the magnet (2465.) which form its boundary, we shall then be able to obtain a clear idea of the direction of the lines of magnetic force in the field. Now the two bodies, P and D, cannot be represented by supposing merely that they have the same polarities in opposite directions. The 1 polarity of P is importantly unlike the 3 polarity of D; but if D be considered as having the reverse polarities of P, then the 1 polarity of P should be like the 4 polarity of D, whereas it is more unlike to that than to the 3 polarity of D, or even to its own 2 polarity.

Fig. 3.



2822. There are therefore two essential differences in the nature of the polarities dependent on conduction, the difference in the direction of the lines of force abutting on the polar surfaces, when the comparison is with a magnet reversed, and the difference of convergence and divergence of these lines, when compared with a magnet not reversed; and hence a diamagnetic body is not in that condition of polarity which may be represented by turning a paramagnetic body end for end, while it retains its magnetic state.

2823. Diamagnetic bodies in media more diamagnetic than themselves, would have the polar condition of paramagnetic bodies (2819.); and in like manner paramagnetic conductors in media more paramagnetic than themselves, would have the polarity of diamagnetic bodies.

2824. Besides these differences the bodies must have an equatorial condition, which, in the two classes of conductors, would be able to produce corresponding effects. The whole of the equatorial part of P (fig. 3) is alike in relation to the body P, or to the lines of force in the surrounding space; and there is a like correspondence in the equatorial parts of D, either to itself or to space; but these parts in P or in D differ in intensity of power one from the other, and both from the general intensity of the space. Such equatorial conditions must, I think, exist as a consequence of the definite character of any given section of the magnetic field (2809.).

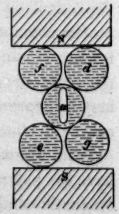
2825. Though the experimental results of these polarities are not absent, still they are not very evident or capable of being embodied in many striking forms; and that because of the extreme weakness of the forces brought into play, as compared with those larger forces exhibited in the mutual action of magnets. Hence it is, that the many attempts to show a polarity in bismuth have either failed, or other phenomena have been mistaken for those properly referable to such a cause. The highest, and therefore the most delicate, test of polarity we possess, is in the subjection of the polar body to the line of direction of magnetic forces of a very high degree, when developed around it; and hence it is, that the pointing of a substance between the poles of a powerful magnet is continually referred to for such a purpose. It would be, and is utterly in vain to look for any mutual action between the poles of two weak paramagnetic or diamagnetic conductors in many cases, when the action of these same poles is abundantly manifest in their relation to the almost infinitely stronger poles of a powerful horseshoe or electro-magnet.

2826. I took a tube *a* (fig. 4), filled with a saturated solution of sulphate of cobalt, and suspended it between the poles of the great electro-magnet; it set readily and well. Another tube, *b*, was then filled with a saturated solution of sulphate of iron, and being associated with the S pole of the magnet, was brought near the cobalt tube in the manner shown, but not the slightest effect on the position of *a* was observable. The tube *b* was changed into the position *c*, to double any effect that might be present, but no trace of mutual action between the poles of *a* and *b* was visible (2819.).

Fig. 4.

2827. To increase the effect, the magnetic solution tube was suspended in water, as a good diamagnetic medium, between flat-faced poles (fig. 5). It pointed well. Two bottles of saturated solution of sulphate of iron were placed at *d* and *e*, but they did not alter the position of *a*; being removed into the positions *f* and *g*, neither was any sensible alteration of the position of *a* produced. I made the same kind of experiment with an air-tube in water, in which case it points axially (2406.), with the same negative result. I do not mean to assert that there was absolutely no effect produced in these cases (2819.); but if any, it must have been inappreciably small, and shows how unfit such means are to compare with those which are supplied by the pointing of a body when under the influence of powerful magnets. If polarity cannot be found by these

Fig. 5.



methods in paramagnetic bodies so strongly influential as saturated solution of iron, nickel or cobalt, it can hardly be expected to manifest itself by analogous actions in the much weaker cases of diamagnetic substances.

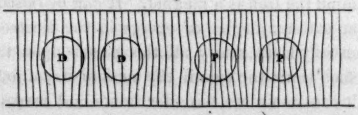
2828. When a spherical paramagnetic conductor is placed midway in a field of equal magnetic force, it occupies a place of unstable equilibrium, from which, if it be displaced ever so little, it will continue to move until it has gained the iron boundary walls of the field (2465. 2810.); this is a consequence of its particular polar condition. If the sphere were free to change its form, it would elongate in the direction of the magnetic axis; or if it were a solid of an elongated form, it would point axially, both consequences of its polar condition (2811.).

2829. So also in the case of diamagnetic bodies, their peculiar condition of polarity is shown by corresponding facts, namely, by a spherical portion having its place of stable equilibrium in the middle of the magnetic field (2812.), by a fluid portion tending to expand equatorially and become an oblate spheroid (2813.), and by the equatorial pointing of an elongated portion (2812.). If pointed magnetic poles are used, then the effects are very much stronger, but are exactly the same in kind, and dependent upon the same causes and polar conditions.

2830. There are another set of effects produced, which are either the results of the axial polarity just referred to, or else may be considered as consequences of the condition of the equatorial parts of the conductors (2824.). Two balls of iron, in a field of equal force, if retained in a plane at right angles to the line of force, *i. e.* with their equatorial parts in juxtaposition, separate from each other with considerable power (2814.), and the probability is that two infinitely weaker bodies of the paramagnetic class would separate in like manner. Two portions of phosphorus, being a diamagnetic substance, have been found also to separate under the same circumstances (2815.).

2831. The motions here are of the same kind, whereas they might have been expected to be the reverse (2816.) of each other; still they are perfectly consistent. The diamagnetics ought to separate, for the field is stronger in lines of magnetic force between them than on the outsides, as may easily be seen by considering the two spheres D D in fig. 6; and therefore this motion is consistent, and is in accordance generally with the opening or set equatorially, either of separate portions or of a continuous mass of such substances (2829.), in their tendency to go from stronger to weaker places of action. On the other hand, the two balls of iron, P P, have weaker lines of force between them than on the outside; and as their tendency is to pass from weaker to stronger places of action, they also sepa-

Fig. 6.



rate to fulfil the requisite condition of equilibrium of forces. Finally, a paramagnetic and a diamagnetic body attract each other (2817.); and they ought to do so, for the diamagnetic body finds a place of weaker action towards the paramagnetic body, and the paramagnetic substance finds a place of stronger action in the vicinity of the diamagnetic body, D P, fig. 6.

2832. I have frequently spoken of iron in illustration of the action of paramagnetic conductors, and considered the polarity which it acquires as the same with that of these conductors; but I must now make clear a distinction, which exists in my mind, with regard to the polarity of a magnet, and the polarity, as I have called it, due to mere conduction. This distinction has an important influence in the case of iron. A permanent magnet has a polarity in itself, which is possessed also by its particles; and this polarity is essentially dependent upon the power which the magnet inherently possesses. It, as well as the power which produces it, is of such a nature, that we cannot conceive a mere space void of matter to possess either the one or the other, whatever form that space may be supposed to have, or however strong the lines of magnetic force passing across it. The polarity of a conductor is not necessarily of this kind, is not due to a determinate arrangement of the cause or source of the magnetic action, which in its turn overrules and determines the special direction of the lines of force (2807.), but is simply a consequence of the condensation or expansion of these lines of force, as the substance under consideration is more or less fitted to convey their influence onwards. It is evidently a very different thing to originate such lines of power and *determine their direction* on the one hand, and only to assist or retard their progression without any reference to their direction on the other. Speaking figuratively, the difference may be compared to that of a voltaic battery and the conducting wires, or substances, which connect its extremities. The stream of force passes through both, but it is the battery which originates it, and also determines its direction; the wire is only a better or worse conductor, however by variation of form or quality it may diffuse, condense, or vary the stream of power.

2833. If this distinction be admitted, we have to consider whether iron, when under the influence of lines of magnetic power, becomes a magnet and has its proper polarity, or is a mere paramagnetic conductor with conducting powers of the highest possible degree. In the first place, it would have the real polarity of the magnet, in the second only that which I assign to oxygen and other conducting bodies. To my mind the iron is a magnet. It can be raised as a *source* of lines of magnetic power to an extreme degree of energy in the electro-magnet; and though, when very soft, it usually loses nearly all this power upon the cessation of the electric current, yet such is not the case if the mass of metal forms a continuous circuit or ring, for then it can retain the force for hours and weeks together, and is evidently for the time an original source of power independent of any voltaic current. Hence I think that the iron under the influence of lines of magnetic power becomes a magnet; and though it then has the same kind of polarity, as to direction, as a mere paramagnetic

conductor, subject to the same lines of force, still with a great difference; for as the internal particles of iron become in a degree each a system producing magnetism, so their polarity is correlated and combined together into a polar whole, which, being infinitely more intense, may also be very different in the disposition of its force in different parts, to that equivalent to polarity, which a mere conductor possesses.

2834. It appears to me also as very probable, that when iron, nickel and cobalt, are heated up to the respective temperatures at which they lose their wonderful degree of power (2347.) and retain only so small a portion of it as to require the most sensible test to make it manifest (2343.), they then have passed into the condition of paramagnetic conductors, have lost all ability to acquire that state of internal polarity they could assume as magnets, and now have no other polarity than that which belongs to them as masses of paramagnetic matter (2819.). It is also probable that in many states of combination these metals may take up the mere conducting state; for instance, that whilst in the protoxide, iron may constitute a magnet, in the peroxide it is only a conductor; and in this respect it is not a little curious to find oxygen, which as a gas is a paramagnetic body (2782.), reducing iron down to, and indeed far below its own condition, weight for weight. In their various salts also and solutions, these metals may, in conjunction with the combined matter, be acting only as conductors.

2835. Perhaps I ought not to have called the condition of concentration or expansion of the lines of magnetic force in the bodies acting as conductors, a polarity; inasmuch as true magnetic polarity depends essentially and entirely on the *direction* of the line of force, and not on any mere compression or divergence of these lines. I have done so only that I might point with the more facility to facts and views that have heretofore been associated with some supposed polarity in the bodies which, whether paramagnetic or diamagnetic, I have been considering as mere conductors, and I hope that no mistake of my meaning will arise in consequence. I have already asked for such liberty in the use of phrases (lines of force, conducting power, &c.) (2149. 2797.) as may, for the time, set me free from the bondage of preconceived notions; these are, for that very reason, exceedingly useful, provided they are for the time sufficiently restricted in their meaning, and do not admit of any hurtful looseness or inaccuracy in the representation of facts.

¶ iii. *Magnecrystallic conduction**.

2836. The beautiful researches of Plücker in relation to magneoptic phenomena cannot have been forgotten, and I hope that my own experiments on magnecrystallic results (2454, &c.) are remembered in conjunction with his; the phenomena described by us are, as I believe, due to a common cause, and are the same in kind; and as far as they are presented by pure transparent bodies, are I think brought by Plücker into

* I must refer here to the important paper by MM. Tyndall and H. Knoblauch on this subject in the Philosophical Magazine, 1850, vol. xxxvii. p. 1. M. F.—January 6, 1851.

a proper relation to the positive and negative optic axis of such bodies*. In these cases a crystalline body sets powerfully, or takes up a particular position when placed in a field of magnetic force (2464. 2479. 2550.), without reference to its paramagnetic or diamagnetic character (2562.), and also without assuming any state which it can on its removal bring away with it (2504.).

2837. If the idea of conduction be applied to these magnecrystallic bodies, it would seem to satisfy all that requires explanation in their special results. A magnecrystallic substance would then be one which in the crystallized state could conduct onwards, or permit the exertion of the magnetic force with more facility in one direction than another; and that direction would be the magnecrystallic axis. Hence, when in the magnetic field, the magnecrystallic axis would be urged into a position coincident with the magnetic axis, by a force correspondent to that difference, just as if two different bodies were taken, when the one with the greater conducting power displaces that which is weaker.

2838. The effect of position would thus be accounted for (2586.); and also the greater aptness for magnetic conduction in one direction than in another (2588. 2591.): and, what appeared to me as an anomaly in the supposition, that a line of force could have reference indifferently to any part of a plane (2600.) disappears. That heat should take away this conducting power (2570.) seemed perfectly consistent with what we know of the effect of heat on the magnetic condition of iron, oxygen, &c., and also upon the conducting power for electricity in such cases as platina, sulphuret of silver, &c. Finally, the assumption did not appear inconsistent with the state which the body seems to assume for the time during which it is under the magnetic force (2609. &c.).

2839. But if such a view were correct, it would appear to follow that a diamagnetic body like bismuth ought to be less diamagnetic when its magnecrystallic axis is parallel (as nearly as may be) to the magnetic axis, than when it is perpendicular to it. In the two positions it should be equivalent to two substances having different conducting powers for magnetism, and therefore, if submitted to the differential balance, ought to present differential phenomena, corresponding in kind to those of oxygen and nitrogen (2774.), or phosphorus and bismuth, or any other two differing bodies. Though I have given certain results on a former occasion which seemed to bear on this point (2551. 2552. 2553.), they are not satisfactory in the present state of our knowledge, because the difference, if any, would be small (2552.), and quickly hidden by the employment of a single pointed pole. Other experiments, formerly described (2554–2561.), would not show a small difference in diamagnetic force (though quite fitted for their intended purpose), because they were made with flat-faced poles, and a field nearly equal in magnetic power.

2840. The differential torsion balance (2773.) enabled me to return to this matter with better hopes of success. A consistent group of bismuth crystals was selected

* Philosophical Magazine, 1849, vol. xxxiv. p. 450.

(2457.) and hung up on one side of the double cone core (2738.), whilst a cylinder of flint-glass was opposed to it on the other. The flint-glass was to be a standard of reference, and therefore neither its place on the balance nor condition was altered during the experiment. The bismuth group was placed with its magnecrystallic axis horizontal, and so that it could be turned in a horizontal plane, that the axis might be at one time parallel to the magnetic axis (or lines of force), and at other times perpendicular to it, but without any alteration of the distance of its centre of gravity from the opposed glass cylinder. Hence, having either one position or the other, it could still be compared with the cylinder.

2841. The magnecrystallic axis was first made parallel to the core or magnetic axis, the magnetic power developed, and when the diamagnetic bodies had taken their position of rest or stable equilibrium, the place of the balance lever was observed and recorded by means of a ray of light reflected from a mirror attached to it. Then the bismuth was turned through 90°, or until its magnecrystallic axis was perpendicular to the axis of the double cone core; and now, when the magnet was excited, the place of the bismuth was found to be further out from the core than before. On being turned through 90° more, so as to be in a position diametral to the first (2461.), its place was again a little nearer to the magnet; and when in the fourth position, which is diametral to the second, then it was further out. Thus the crystallized bismuth proved to be diamagnetic in different degrees, according with certain directions of its magnecrystallic axis, being more diamagnetic when this axis was perpendicular or transverse to the lines of magnetic force, than when it was parallel to them; and thus the expectation founded upon theoretical considerations (2839.) was confirmed.

2842. I tried to obtain similar results with a cube of calcareous spar (2597.); for it is evident that if its optic axis, being in a horizontal plane, is first placed parallel to the magnetic axis and then perpendicular to it, the body ought to be more diamagnetic in the first position than in the second, inasmuch as the latter is the position which it takes up under the influence of its magnecrystallic or magneoptic condition. I could not however obtain any distinct results, partly because its power is in all respects very inferior to the bismuth, partly because of the present imperfection of my torsion balance, and partly because of the size and shape of the calcareous spar. A sphere or a cylinder, having the optic axis perpendicular to the axis of the cylinder, would be more correct as forms of the substances to be tried.

2843. In concluding this part of the subject relating to the magnetic conducting power, I will now refer to some of the cases which I think experimentally establish its *existence* in the two subdivisions of magnetic bodies (2805.). The place and position of iron in a field of equal force (2810. 2811.) is no doubt a result of the extraordinary power which this body has of transmitting the magnetic force across the space which it occupies, whether the particles of the iron be considered as polar or not

(2832.), and therefore I accept the converse phenomena as to place and position of a diamagnetic body (2812. 2813.) as proof that it has less power of transmitting the magnetic force than the space it occupies, and from that conclude that it conducts diamagnetically (2802.).

2844. The separation of paramagnetic bodies in the equatorial direction is a proof of the manner in which, by their better conduction, they disturb the position of the lines of force in the medium around them (2831.). The separation of two diamagnetic bodies, under the same circumstances, is an equal proof of the manner in which, by difference of conducting power, they also disturb the disposition of the force (2831.). The equatorial attraction of a paramagnetic and a diamagnetic body for each other, when they are in a medium, which in conducting power is between the two (2831.), is a proof not only of conduction in both, but also of their reverse condition in respect of each other and the medium.

2845. The place of a crystal of bismuth, either nearer to or further from the magnetic axis (2841.), according as its magnecrystallic axis is parallel or perpendicular to the axial line, is also a case of the difference of conducting power, and therefore of the possession of that power by the diamagnetic body. Many other cases might be quoted in illustration of the existence of that power which I assumed as conducting power (2797.), and which probably nobody may be inclined to deny. I will suppose that the above are enough to explain my meaning.

2846. It is hardly necessary for me to say that magnetic conduction does not mean electro-conduction, or anything like it. The very best electro-conductors, as silver, gold and copper, are below mere space in their ability to favour the transmission of magnetic force, so deficient are they in what I have called magnetic conduction. There is a striking analogy between this conduction of magnetic force and what I formerly called specific inductive capacity (1252. &c.) in relation to static electricity, which I hope will lead to further development of the manner in which lines of power are affected in bodies, and in part transmitted by them.

¶ iv. *Atmospheric magnetism**†.

2847. It is to me an impossible thing to perceive, that two-ninths of the atmosphere, by weight, is a highly magnetic body, subject to great changes in its magnetic

* A most important paper by Professor CHRISTIE "On the Theory of the Diurnal Variation of the Magnetic Needle," appears in the Philosophical Transactions for 1827, p. 308. Led by the discoveries of SEEBECK in thermo-magnetism and the experiments of CUMMING, he was induced to search how far the idea of thermo-currents or thermo-magnetic polarity would apply to the natural phenomena, and concludes (p. 327), that, admitting that the *earth and the atmosphere* are substances in which such action can under any circumstances take place, these experiments would indicate that *any portion of the earth bounded by parallel planes with the atmosphere surrounding it, would become similarly polarized if one part were more heated than another*. Thus considering alone *the equatorial regions of the earth*, we should have *two magnetic poles on the northern side, and on the southern side two poles similarly posited; the poles of different names being opposed to each other on the contrary sides of the equator*.

† I ought to refer the readers of my paper to a theory of the *cause* of the daily variations by M. A. DE LA

character, by variations in its physical conditions of temperature and condensation or rarefaction (2780.), and at the same time subject to these physical changes in a high degree, by annual and diurnal variations, in its relation to the sun, without being persuaded that it must have much to do with the disposition of the magnetic forces upon the surface of the earth (2796.), and may perhaps account for a large part of the annual, diurnal and irregular variations, for short periods, which are found to occur in relation to that power. I cannot pretend to discuss this great question with much understanding, seeing that I have very little of that special knowledge which has been accumulated by the exertions of the great and distinguished labourers, HUMBOLDT, HANSTEEN, ARAGO, GAUSS, SABINE, and many others, who have wrought so zealously at terrestrial magnetism over the surface of the whole earth. But as it has fallen to my lot to introduce certain fundamental physical facts, and as I have naturally thought much upon the general principles which tend to establish their relation to the magnetic actions of the atmosphere, I may be allowed to state these principles as well as I can, that others may be placed in possession of the subject. If the principles are right, they will soon find their special application to magnetic phenomena as they occur at various parts of the globe.

2848. The earth presents us with a spheroidal body, which, consisting of both paramagnetic and diamagnetic substances, disposed with much irregularity as regards its large divisions of earth and ocean, are also equally irregularly disposed and intermingled in its smaller portions. Nevertheless it is, on the whole, a magnet, and, as far as we at this moment are concerned, an original source of that power. And

RIVE, founded upon the idea of thermo-electric currents in the atmosphere and earth; it will be found in a memoir entitled 'On the Diurnal Variation of the Magnetic Needle.' Annales de Chimie, 1849, XXV. p. 310.

A friend has recently called my attention to an observation by M. E. BECQUEREL, which has reference to the present subject, and is in the following words. "If we reflect that the earth is encompassed by a mass of air, equivalent in weight to a layer of mercury of 30 inches, we may inquire whether such a mass of magnetic gas, continually agitated and submitted to the regular and irregular variations of pressure and temperature, does not intervene in some of the phenomena dependent on terrestrial magnetism. If we calculate in fact what is the magnetic force of this fluid mass, we find that it is equivalent to an immense plate of iron, of a thickness a little more than $\frac{1}{10}$th of a millimetre of diameter (?), and which covers the whole surface of the globe." This passage is at pp. 341, 342 of vol. xxviii. Annales de Chimie, 1850, being contained in an excellent memoir, in which the author has well worked out those differential actions of different media, which I developed generally *five* years ago. Experimental Researches, 2357. 2361. 2406. 2414. 2423. &c. By such means he has rediscovered the magnetic character of oxygen and taken measurements of its force, being evidently unacquainted with the account that I gave of this substance in relation to nitrogen and other gases *three* years ago, in a letter published in the Philosophical Magazine for 1847, vol. XXXI. p. 401, and also in POGGENDORFF's Annalen and elsewhere;—hence the observations above. I cannot wonder at this, for I myself was not aware of M. E. BECQUEREL's paper until very lately. In my letter of 1847, I speak of oxygen as being magnetic in common air, p. 410; in carbonic acid, p. 414; in coal-gas, p. 415; in hydrogen, p. 415, its power then being equal to its gravity. I say that air owes its place to the oxygen and nitrogen in it, p. 416, and tried to separate these constituents by attracting the oxygen and repelling the nitrogen. At the end of the paper I hesitate in deciding where the true zero between magnetic and diamagnetic bodies is to be placed, and refer to the atmosphere as being liable to affections under the magnetic influence of the earth. It was these old results which led me on to the present researches. M. F.—Nov. 28, 1850.

though we cannot conceive at present that all the particles of the earth contribute, as sources, to its magnetism, inasmuch as many of them are diamagnetic, and many non-conductors of electric currents, yet it is difficult to say that any large portion is not concerned in the production of the force; hereafter it may be necessary, perhaps, to consider certain parts as mere conductors, *i. e.* as parts merely permeated by the lines of force, originating elsewhere, but for the present the whole may be assumed, according to the theory of GAUSS, as a mighty compound magnet.

2849. The magnetic force of this great system is disposed with a certain degree of regularity. We have the opportunity of recognising it only as it is exhibited in one surface, which, being very irregular in form, is always the same to us, for we rarely, if ever, pass out of it; or if we do, as in a balloon, only to an insensible extent. This is the surface of the earth and water of our planet. The magnetic lines of force which pass in or across *this surface* are made known to us, as respects their direction and intensity, by their action on small standard magnets; but their average course or their temporary variations *below or above*, i. e. in the air above, or the earth beneath, are only dimly indicated by variations of the force at the surface of the earth, and these variations are so limited in their information, that they do not tell us whether the cause is above or below.

2850. The lines of force issue from the earth in the northern and southern parts with different but corresponding degrees of inclination, and incline to and coalesce with each other over the equatorial parts. Their general disposition is represented by the system, which emanates from a globe having within one or two short magnets adjusted in relation to the axis. There seems reason to believe, from the analogy of such globes to the earth, that the lines of magnetic force which proceed from the earth return to it; but in their circuitous course they may extend through space to a distance of many diameters of the earth, to tens of thousands of miles. Messrs. GAY-LUSSAC and BIOT, in their ascent in a balloon, perceived some indication of a diminution in the intensity of the magnetic force at a height of about four miles from the surface; but we shall shortly perceive that they might be at the time in the midst of influences sufficient to account for all the effect, so that none of it might be occasioned by removal from the earth as a magnet. The increase of the intensity of the magnetic force, as we proceed from the equator towards the poles, accords with the idea of the enormous extension of this power.

2851. These lines proceed through space with a certain degree of facility, of which a general idea may be gained from ordinary knowledge, or from experiments and observations formerly made (2787.). Whether there are any circumstances which can affect their passage through mere space, and so cause variations in their condition; whether variations in what has been called the temperature of space could, if they occurred, alter its power of transmitting the magnetic influence, are questions which cannot be answered at present, although the latter does not seem to be entirely beyond the reach of experiment.

2852. This space forms the great abyss into which such lines of force as we are

able to take cognizance of by our observing instruments, which issue from the earth, proceed, at least at all parts of the globe where there is a sensible dip; but, as it were, between the earth and this space, there is interposed the atmosphere, which, however considerable we may estimate it in height, is so small when compared to the size of the earth, or to the extent of space beyond it into which the lines of force pass, that the idea of its being a changeable, active something interposed *between* two systems far more extensive and steady in their nature and condition, will not lead to any serious error. It is at the bottom of this atmosphere that we live and make all our inquiries, whether by observation or experiment.

2853. The atmosphere consists, as far as we are concerned at present, of four volumes of nitrogen and one volume of oxygen, or by weight, of three and a half parts of the former and one part of the latter. These substances are nearly uniformly mixed throughout, so that, as regards their manner of investing the earth, they act magnetically as a single medium; nor does there seem to be any tendency in the terrestrial magnetic forces to cause their separation*, though they differ very strikingly in their constitution as regards this power.

2854. *The nitrogen* of the air does not appear to be either paramagnetic or diamagnetic; if removed from zero, in either of these respects, it is only to a very small extent (2783. 2784.). Whether dense or rare, it has apparently the same relation to and equality with space, as far as the present means of observation have proceeded. As respects the other element of change, namely, temperature, I concluded, from former imperfect experiments†, that nitrogen became more diamagnetic when heated than before; but as it was then mixed with the oxygen of the air, and the results were mingled together, I have, for the purposes of the present research, repeated the experiments far more carefully.

2855. A small helix of platinum wire, fixed at the end of thicker copper wires, could be placed in any position beneath the poles of the great electro-magnet, and being ignited by a voltaic battery, served to raise the temperature of the gas around it. The magnetic poles were raised, were terminated by hemispheres of soft iron 0·76 of an inch in diameter and 0·2 of an inch apart, and were covered by a glass shade, resting upon a thick flat bed of vulcanized caoutchouc. A tube passed through the bed, rising up to the top of the shade, by which any required gas could be introduced. A very thin plate of mica, about 3 inches square, was covered with an attenuated coat of wax on the upper side, and fixed horizontally over the magnetic poles within the shade. The small platinum helix was so placed as to be beneath the space, between the poles, and a little on one side of the axial line, so that a current of hot air rising upwards from it, could pass to the mica plate, and by melting the wax show where it came against the mica.

2856. All acted exceedingly well, *air* being in the glass shade. When there was no magnetic power on, the hot air from the ignited helix rose perpendicularly, and

* Philosophical Magazine, 1847, vol. xxxi. p. 416. † Ibid. p. 418.

melted a neat round portion of the wax, showing the place of the current under natural circumstances; but when the magnet was thrown into action, then the wax on the mica remained unchanged, the hot air being thrown so far away from the axial line, and so cooled by its forcible mixture with the neighbouring air, as to be unable to melt a spot of wax anywhere. The moment the magnetic power was suspended, the column of hot air rose vertically and regained its original position.

2857. *Carbonic acid gas* was then sent into the shade, until twice as much as the contents of the shade had passed through the pipe (2855.); but as it was heavy and the common air could make its way out only at the bottom of the shade, there was no doubt air mixed with the carbonic acid, which at last remained about the poles. The platinum coil being now heated, the column of hot gas rose vertically, as before. On putting on the magnetic force it was deflected from the axial line, passing equatorially, and melted the wax about half an inch off from the former place. Believing that even this effect might be due to the air mingled with the gas, other two volumes of carbonic acid gas were directed into and through the vessel. After this the magnetic force caused much less deflection of the rising column. Two volumes more of carbonic acid were sent through, and now the hot current of gas rose so nearly vertical that there was scarcely any sensible difference of its place when the magnetic power was in full action, or when it was entirely absent. Hence I conclude that carbonic acid gas is very little affected in its diamagnetic relations by a difference of temperature equal to that between natural temperatures and a full red heat.

2858. *Nitrogen.*—This gas was prepared by passing common air slowly over burning phosphorus, and after being washed for twelve or fourteen hours, was sent into the shade so as to displace the carbonic acid. As it was lighter than the latter, it performed that service very well, and the portion remaining in the vessel probably contained no other oxygen or air than that it carried in with it. This nitrogen being then heated by the platina coil, was almost as indifferent to the magnet as the carbonic acid. The heated column rose (nearly) to the same spot against the mica, whether the magnetic power was active or not. It went outwards or equatorially a very small degree when the magnet was active, but this I attributed to a little oxygen still left with the nitrogen; and indeed nitric oxide gas shows oxygen in nitrogen so prepared. The platina coil was raised to as high a temperature as it could well support without fusion, and yet there was only this small effect sensible; hence I conclude that hot nitrogen is not more diamagnetic than cold nitrogen, and that indeed its magnetic relation is noways affected by such change of temperature.

2859. I raised the French shade (2855.) an inch for a moment, and then instantly placed it down again; and now, on making the magnet active and the coil hot, there was so much effect of dispersion of the gas within, that the melted spot of wax appeared nearly an inch outside of the standard place, yet only a very small portion of air or of oxygen could have entered the vessel under these circumstances.

2860. The nitrogen of the air is therefore, as regards the magnetic force, a very

indifferent body; it does not appear to be either paramagnetic or diamagnetic; neither does it present any difference in its relation, whether it be dense or rare, or at high or low temperatures. I formerly found that the diamagnetic metals, when heated, did not seem to change in their relation to the magnet (2397.), and this now appears to be the case with such neutral or diamagnetic bodies as nitrogen and carbonic acid gases.

2861. *The oxygen* of the air differs in a most extraordinary degree from the nitrogen. It is highly paramagnetic, being, bulk for bulk, equivalent to a solution of protosulphate of iron, containing, of the crystallized salt, seventeen times the weight of the oxygen (2794.). It becomes less paramagnetic, volume for volume (2780.), as it is rarefied, and apparently in the simple proportion of its rarefaction, the temperature remaining the same. When its temperature is *raised*, the expansion consequent thereon being permitted*, it loses very greatly of its paramagnetic force; and there is sufficient reason, from a former result with air†, to conclude, that when its temperature is lowered its paramagnetic condition is exalted. How much its paramagnetic intensity might be increased by lowering it to the temperature of freezing mercury, as at the north or south poles of the earth, we cannot at present tell. Though a gas, it is apparently like the solid metals, iron, nickel or cobalt, when they are within the range of temperature which affects their magnetic forces; and it may, perhaps, like them, rise by cooling to a very high state.

2862. These relations it preserves when mingled with nitrogen in the air, as long as its physical and chemical conditions remain unchanged; but it is not irrelevant to remark, that every operation by which this active part of the atmosphere changes in its nature and passes into combinations, takes away its paramagnetic powers, whether the result be solid, liquid or gaseous.

2863. Hence the atmosphere is, in common phrase, a highly magnetic medium. The air that stands upon every square foot of surface on the earth, is equivalent, in magnetic force, to 8160 lbs. of crystallized protosulphate of iron (2794. 2861.). This medium is, by every change in its density, whether of the kind indicated by the barometer, or caused by the presence or absence of the sun, changed in its magnetic relations. Further, every variation of temperature produces apparently its own change of force, in addition to that caused by the mere expansion or contraction in volume, and none of these alterations can happen without affecting the magnetic force emanating from the earth, and causing variations, both in its intensity and direction, at the earth's surface. Whether these changes are in the right direction and sufficient in quantity to supply a cause for the variations of the terrestrial magnetic power, is the point now to be considered, for the illustration of which I will endeavour to construct a type case, and then apply it, as well as I can, to the natural facts.

2864. Let us assume the existence of two globes of air distinct from the surrounding atmosphere, by a difference of temperature or by a difference of density: the

* Philosophical Magazine, 1847, vol. xxxi. p. 417. † Ibid. p. 406.

assumption is not too extravagant for an illustration, since PROUT showed that there were masses of air, larger or smaller, floating about in the atmosphere, and singularly distinct from the surrounding parts, by temperature and other circumstances. Not to complicate the expression, we will leave out of view, at present, the attenuation upwards, and will consider one of these globes as *colder* or denser than the contiguous parts, and that it is in a portion of space which without it would present a field of equal magnetic force, *i. e.* having parallel lines of equal intensity of force passing across it.

2865. The air of such a globe will *facilitate* the transmission of the magnetic force through the space which it occupies (2807.), making it superior, in that respect, to the surrounding atmosphere or space, and therefore more lines of magnetic force will pass through it than elsewhere (2809.). The disposition of these lines, in respect of the line of the dip of the place, will be something like what is represented in fig. 7, (2874.), and consequently the globe will be polarized as a conductor (2821. 2822.) of the paramagnetic class. Hence the intensity of the magnetic force and its direction will vary, not only within but without the globe, and these will vary in opposite directions, in different places, under the influence of laws which are perfectly regular and well known.

2866. First, as regards the *intensity*, which before was uniform (2864.). If the intensity is to be considered as expressing the amount of force which passes through any given place, then, in consequence of the definite amount of power which belongs to any section, as *a a*, of a given amount of lines of magnetic force (2809.), a concentration of these lines towards the middle, P, will cause an increase of intensity at that part, and a diminution at some other parts, as *b b*, from whence the influence of the power has been partly removed. Hence, supposing the normal condition to exist at *a*, if a test of intensity were carried from *a* to P, it would gradually enter parts *b* and *c*, in which the intensity was less than the normal condition, and these might be either without or within the globe P, or both (according to its temperature relative to the surrounding air, its size and other circumstances); it would then arrive at parts having the normal intensity; and lastly, at parts, P, having an intensity greater than the surrounding space; as it went outwards, on the opposite side of P, corresponding variations would occur in the reverse order.

2867. On transporting the test upwards, in the direction of the dip from *e*, where the intensity may be considered as normal, it would gradually occupy positions at *f g*, &c., in which the intensity would increase until it arrived at P, after which it would pass through places of less and less intensity, until at *p* it would again find the force in the normal state. If the test, in being carried upwards, be not taken along *the line of the dip*, then it will of course pass through variations like those described on the line *a* P, growing more and more in extent until the direction coincides with the line *a* P, which is at right angles to the dip and where they are at a maximum. Hence, to pass upwards through such a globe of cold air in our latitude, where the

dip is 70° nearly, and at the equator, where it is 0°, would be a very different matter, and the necessary natural results of such a difference ought to appear hereafter.

2868. But a magnetic needle or bar is not a test of such intensity, *i. e.* it will not tell these differences, or it may tell them in a contrary direction. To understand this point, we have to consider that a needle vibrates by gathering upon itself, because of its magnetic condition and polarity, a certain amount of the lines of force, which would otherwise traverse the space about it; and assuming that it underwent no change by change of temperature, it would be affected in proportion to any variations in the intensity of these lines, provided everything else remained the same. But being under natural circumstances surrounded by the atmosphere, which is a medium liable to variation in its magnetic condition, both by heat and rarefaction, and by these variations affects the intensity or quantity of the force, it will vary in its indications by variations in these conditions. Thus, for instance, if it were in a large sphere of oxygen, I expect that it would, by its number of vibrations or otherwise, indicate a certain intensity; if the oxygen were expanded, that it would indicate a higher intensity, although the same amount of lines of force and magnetic energy were passing through the oxygen as before. If the oxygen were made dense, then becoming a better conductor, I presume it would convey onwards *more* of the force and the magnet *less*, for the power would be partly transferred from the unchanging magnet to the improving conductor around it.

2869. These experiments can hardly be made with oxygen except by means of extremely delicate apparatus, but like effects are easily shown experimentally in selected analogous cases. Thus let a thin small tube of flint-glass, about 1 inch long and $\frac{1}{2}$ an inch in diameter, be filled with a saturated solution of protosulphate of iron, and suspended horizontally by cocoon-silk (2279.) between the poles of the electro-magnet, in a vessel which may either contain air or water, or other media (2406.). In air it will point axially, and will be analogous to a needle under the earth's influence, and it will point with a certain amount of force. Fill the vessel with water, and now it will point with more force than before, though the water is a worse magnetic conductor than the air which was previously there; and it is precisely because the water *is* a worse conductor that the liquid magnet or test indicates more power. Increase the conducting power of the surrounding medium by adding sulphate of iron to it, and the indication of strength by the tube goes on diminishing, first returning to the degree of power it had in air, and then descending to lower gradations, for it returns with less and less force to its axial position when disturbed from it. So the magnetic needle employed for measuring intensity or magnetic force (for the same meaning is at present understood by the two terms), indicates, in a certain manner, the power thrown upon itself, and, I conclude, accurately, provided the condition of the surrounding medium remains magnetically unchanged; but if it be placed in different media or in an altering medium, I expect that it will not measure accurately the intensity in them, *i. e.* it will not measure directly the amount of force passing relatively

through them. The difference in air under different conditions would be very small, still it is that difference which concerns us in *atmospheric magnetism*; and it is very important to know, whether, when the magnet indicates an increased intensity of force, it is altogether due to a real increase of the amount of the power at its source as it comes to us from the earth, or in part to a change in the magnetic constitution of the space around the magnet hitherto unknown to us.

2870. If what is now often indifferently called magnetic force or intensity have its results distinguished as of two kinds, namely, those of *quantity* and those of *tension*, then we shall more readily comprehend this matter. At present a needle shows both these as magnetic force, making no distinction between them, yet they produce effects on it often in opposite directions; for as they increase or diminish they both affect the needle alike; but as it is assumed that the tension can change whilst the quantity remains the same, and the quantity can be altered, yet the tension remain unaffected, the result by the needle will then be uncertain. If the tension in a given region be increased by diminishing the conducting power, the needle will show *increased force*; if it be increased by an increase of magnetic power in the earth from some internal action, the needle will still show *increased force*, and will not distinguish the one effect from the other. If the quantity in a region be increased by increasing the conducting power, the needle will show no such increase; on the contrary, it will indicate *diminution* of force, because the tension is diminished; or if the quantity be diminished by diminishing the conducting power, it will show *increased* force. The force might even lose in quantity and gain in tension in such proportions that the needle should show no change; or it might gain in quantity and lose in tension, and the needle still be entirely indifferent to the whole result.

2871. If my view be correct, then the magnet is not, as at present applied, a perfect measure of the earth's magnetic force; for that may not change when the magnet by the influence of the different conditions of day and night, or of summer and winter, may show a difference. How *far* these uncertainties in its indication may affect the value of the observations made on the horizontal and vertical components of the earth's magnetic force as indications of that which they are expected to tell us, I do not know; but involving, as the effects do, two very different conditions, namely, variation of the conducting power and variation of the amount of force at its source, the one of which is chiefly in the atmosphere and the other in the earth, it seems to me to be of great consequence to the development of the theory of terrestrial magnetism, to have some method, if possible, of distinguishing these two points or effects from each other.

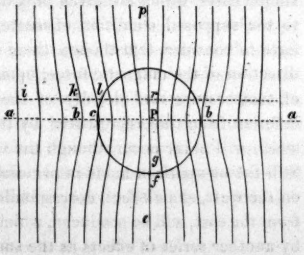
2872. Referring again to the model globe, fig. 7 (2874.), it appears to me, that if a magnet be used as the intensity test, it will indicate a less intensity at P rather than a greater one, for the very reason that the conducting power of the whole globe has been increased; and also, though the apparent diminution of intensity will probably be greater there than elsewhere, that the effect will occur in other parts, espe-

cially those on the right and left, and even at *b* and *b*, where the power transmitted, instead of being more, as at P, is really less than the portion transmitted in the normal or equable state of the magnetic field. With a diamagnetic globe of air, *i. e.* one warmer or more rarefied than the surrounding space (2877.), though it would convey less power as being a worse conductor, still it should cause the magnet to set with greater force, and so give an indication of increased intensity, and that also both within and equatorially without the globe.

2873. If it be true that the changes of the medium (2869.) can thus affect the magnet, and that such changes can rise up to a sensible degree in the gases, then a magnet might make a different number of vibrations in a given time in oxygen and nitrogen gases of the same density, for they are very different in their magnetic relations. It should make the greatest number in nitrogen; perhaps a delicate torsion balance would be a still more sensible test of such a result; but it is probable that the space around the needle should be large, and it would be requisite to ascertain that the two media opposed equal mechanical resistance to the vibrating needle.

2874. The variation of the *direction* caused by the typical globe (2864.) might be oblique to the horizontal and vertical planes, and consequently give results of declination and inclination, either separately or together. The direction would not vary in a central line parallel to the general dip of the surrounding space (fig. 7). Along another central line perpendicular to this (*i. e.* any line in the equatorial plane), *a* P, there would also be no variation of the direction, but in any other position there would be variations. Thus in the line *i r*, as the free needle passed from *i* to *k*, its lower end would be carried inwards towards the central line of dip P; this effect, after attaining a maximum, perhaps at *l*, would gradually diminish again, and by the time the needle had reached *r* the dip would be normal. Corresponding effects would occur on the opposite side of the axial line *p e*; and if a needle be considered as in any place the dip of which is thus affected, and then be conceived as travelling in a circle round the axial line *p e*, it would always be in the surface of a cone, the apex of which is below.

Fig. 7.

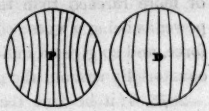


2875. On the other hand, if the variations of the dip below the equatorial plane *a* P be considered, they will be equal in amount, but in the reverse direction, so that the magnetic needle, when deflected from its normal position, would have its upper end inclined inwards towards the axial line *p e*; or if moved round the axial line would always be in a conical surface, the apex of which is above.

2876. So the dip would vary in such a globe of air in every azimuth; and it would also vary in opposite directions in the upper and lower parts of the globe, and of the affected surrounding space.

2877. If we assume the existence of another typical globe of air (2864.), having a higher temperature than the surrounding atmosphere, then its condition will be that of a diamagnetic conductor, and will be represented by fig. 9 (2807.); and it will have power to affect both the intensity and the direction of the lines of force, in conformity with the action of the former globe, but in the contrary order. As regards the action of these globes, consequent upon the direction of the lines of force in and about them upon a needle coming within their influence, it may, in part, be represented by a magnet placed either in the direction of the needle for the cold globe, or in the reverse direction for the warm one; but as the lines of force of the combined system of the earth and such a magnet are very different in their arrangement to the lines of the earth affected by masses of warm or cold air having only conduction polarity (2820.), it would be too much to say that they correspond, or that the effects on the intensity or direction would be the same for similar distance from the centre of the globe of air and the representative magnet.

Fig. 8. Fig. 9.



2878. In endeavouring to proceed, from these hypothetical and comparatively simple cases, which are given only to lead the mind on from the results of experiment to the supposed condition of matters as regards our atmosphere and the earth, we have to consider, that though there will be an effect, and though the intensity and direction of the magnetic force, upon the surface of the earth, must vary with changes of temperature and density of the atmosphere, still it will be in a manner very different from that represented by the typical globe of air, for the latter is a case which will never occur, though the variations of the natural case are almost infinite. Still the comparison holds in principle, and we may expect that as the sun leaves us on the west, some effect, correspondent to that of the approach of a body of cold air from the east, will be produced, which will increase and then diminish, and be followed by another series of effects as the sun rises again and brings warm air with him.

2879. The atmosphere diminishes in density upwards, and that diminution will affect the transmission of the magnetic force, but as far as it is constant, the effect produced by it will be constant too. The portion of the atmosphere which lies under the heating influence of the sun, as compared to its depth, will more resemble a slice of air wrapped round the earth than a globe. Still the inflection of the lines of force, both above and below this stratum, will occur, extending into space above and into the earth beneath (2848.), according to the known influence of magnetic power and its perfectly definite character (2809.). We are placed at the bottom of this layer of air, but as the atmosphere is denser there than higher up, and is also in many cases more affected there by changes of temperature, we are probably in a position where the inflections and variations due to the assumed causes exist in a considerable degree.

2880. There are innumerable circumstances that will break up, more or less, any

general or average arrangement of the air temperature. For instance, the diversity of sea and land causes variations of temperature differently in different times of the year, and the extent to which this goes may be learned from the beautiful isothermal charts of Dove, now fortunately to be had in this country*. These variations may be expected to give, not merely differences in the regularity, direction and degree of magnetic variation; but because of vicinity differences so large as to be manifold greater than the mean difference for a given short period, and they may also cause irregularities in the times of their occurrence.

2881. On considering the probable results of the magnetic action of the atmosphere, it appears to me that if the terrestrial magnetic force could be freed from all periodical and small perturbations, and its disposition ascertained for any given time, it might still include certain effects constituting a part of atmospheric magnetism. For instance, there is more air, by weight, over a given portion of the surface of the earth at latitudes from 24° to 34°, than there is either at higher latitudes or at the equator; and that should cause a difference from the disposition of the lines of force which would exist if there were equality in that respect, or if the atmosphere were away. Again, the temperature of the air is greater at the equatorial parts than in latitudes north or south of it; and as elevation of temperature diminishes the conducting power for magnetism, so the proportion of force passing through these parts ought to be less, and that passing through the colder parts greater, than if the temperature of the air were at the same mean degree over the whole surface of the globe, or than if the air were away. Again, there is a greater difference in range of temperature of the air at the equator as we rise upwards than in other parts, and hence the lower part is not so good a conductor proportionately to the upper part, or to space, as elsewhere, where the difference is not so great; the magnetic power, therefore, should be in some degree weakened there, the lines of force being diverted, more or less, from the warm air and thrown into other parts, as the cooler atmosphere and space above, or the earth beneath, according to the principles before explained (2808. 2821. 2877.).

2882. The result of *annual variation* that may be expected from the magnetic constitution and condition of the atmosphere seems to me to be of the following kind. Assuming that the axis of rotation of the earth was perpendicular to the plane of its orbit round the sun, and dismissing for the present other causes of magnetic variation than those due to the atmosphere, the two hemispheres of the earth, and the portions of air covering them, would be affected and warmed alike by the sun, or at least would come into a constant relative state, dependent upon the arrangement of land and water; and the lines of magnetic force having taken up their position under the influence of the great dominant causes, whatever they may be, would not be altered by any annual change due to the atmosphere, since the daily mean of the

* Report of the British Association, 1848, Reports, p. 85.

atmospheric effect in a given place would at all parts of the year be alike. Under such circumstances the intensity and direction of the magnetic forces might be considered constant, presuming no sensible change to take place by the difference in distance from the sun which would occur in different parts of the orbit; and, as regards the two magnetic hemispheres, each would be the equivalent of and equal to the other, and they may for the time be considered in their mean or normal state.

2883. But as the axis of the earth's rotation is inclined 23° 28′ to the plane of the ecliptic, the two hemispheres will become alternately warmer and colder than each other, and then a variation in the magnetic condition may arise. The air of the cooled hemisphere will conduct magnetic influence more freely than if in the mean state, and the lines of force passing through it will increase in amount, whilst in the other hemisphere the warmed air will conduct with less readiness than before, and the intensity will diminish. In addition to this effect of temperature, there ought to be another due to the increase of the ponderable portion of the air in the cooled hemisphere, consequent upon its contraction and the coincident expansion of the air in the warmer half, both of which circumstances tend to increase the variation in power of the two hemispheres from the normal state. Then as the earth rolls on in its annual journey, that which at one time was the cooler becomes the warmer hemisphere, and consequently in its turn sinks as far below the average magnetic intensity as it before had stood above it, whilst the other hemisphere changes its magnetic condition from less to more intense.

2884. As the sum of the magnetic forces which crop out from the earth wherever there is dip on one side of the magnetic equator must correspond to the sum of like force on the other side (2809.), so they would not become more intense in one hemisphere, or more feeble in the other, without a corresponding contraction on the one hand, and enlargement on the other. The line of no dip round the globe may therefore be expected to move alternately north and south every year, or some effect equivalent to that take place. The condition of the two hemispheres under this view may be conceived by supposing an annual undulation of the force to and fro between them, during which, though neither the character nor the general disposition of the power be altered, there is in our winter a concentration and increase of intensity in the northern parts coincident with a diffused and diminished intensity in the south, and in summer the reverse.

2885. In respect of *direction*, alterations may also be anticipated. In the first place, and assuming that the magnetic poles and the poles of the earth coincide, the dip would increase in the cooling hemisphere towards the middle and polar parts; but it ought to diminish towards the magnetic equator, to accord with the concentration of the hemisphere of stronger power and enlargement of the weaker one; whilst on the other hand the dip ought to diminish at the polar and middle parts of the warming hemisphere and increase towards the magnetic equator. The magnetic equator would shift a little north and south of its mean place during each year, simultaneously

with the whole system of magnetic lines. But as the magnetic poles do not coincide with those of the earth, or with what may be called the poles of the changing temperatures, so a cause of difference in direction will here arise.

2886. Again, it may be that as oxygen is cooled, its paramagnetic power may increase in a more rapid proportion than that of the change of temperature, so that the chief alteration of the disposition of the earth's force may be in the extreme northern and southern parts; and in combination with the holding power of the earth (2907.) may even cause a change the reverse of that expected above in lower latitudes. If in our winter the lines of force were to close together in the polar parts and to open out in lower latitudes, the balance of magnetic force would just as well be sustained as if *all* the lines in our hemisphere were to be compressed and strengthened, and be compensated for by a corresponding change in the south. In the former case, each hemisphere would balance its own forces, in the latter they would be balanced against each other. There can, I think, be no doubt, that as far as the mass of the earth and the space above our atmosphere are unchangeable in relation to annual and diurnal variation, so far they would tend to restrain any variation which might depend only on the varying temperature and state of the air; holding as it were the two sides of the variations, the increase and diminution of intensity, or the right and left hand in change of direction, nearer together than they otherwise would be.

2887. Further, if it be supposed that the whole of a hemisphere *is affected at once* in the same direction by change of temperature, it will *not be affected alike, but differently in different latitudes*, because of the difference in amount of that change.

2888. The difference of land and water (2880.) will still further break up any expected uniformity of the general result, and cause that certain parts of the cooling hemisphere shall increase in power more in proportion than other parts; and when these parts lie on opposite sides of the magnetic meridian of any given place, they would probably have power to cause an alteration in the declination of the needle at that place.

2889. As the annual changes of temperature are less at the equator than in parts more north or south, so there, probably, little or no annual variation would occur: none indeed as regards the varying temperature or expansion of the air, but only that portion which is consequent upon the alternate changes of the parts on its opposite sides (2884.).

2890. Another effect, which may be considered as an annual variation, but which is connected with the diurnal change, may be expected. As the daily changes in temperature of the atmosphere, influential upon a given place in north or south medium latitudes, are greater in extent in summer than in winter, so the corresponding magnetic variations may be expected to vary also, being larger in the northern hemisphere, when the sun is on the north side of the equator, and less when he is present in the southern hemisphere, and producing like correspondent change there.

2891. From a most important investigation by Colonel SABINE*, founded on the results of observations at Toronto and Hobarton, the facts appear to be that the magnetic intensity is greater in both hemispheres in those months which are winter in the northern hemisphere, and summer in the southern. Similar results are greatly wanted for other localities, and would show whether the different disposition of land and sea has anything to do with the question, or whether the results at Toronto and Hobarton are true exponents of hemispherical effects. Assuming Toronto and Hobarton as being such exponents, the dip in both hemispheres is greater (i. e. greater north dip at Toronto and south dip at Hobarton) in those months which are winter in the northern, and summer in the southern hemisphere. Whether there is any *annual* variation of the dip or total force in the equatorial parts of the globe is very important to determine. It would be well worth while to take up a station for the express purpose; the instruments are very simple, and the observations would require only a single observer. They are described in the paper referred to. Unfortunately such observations are not even made in Great Britain.

2892. The manner in which the diurnal variation may be produced or affected by the action of the sun on our atmosphere as the earth revolves in its beams, has been already generally referred to. The whole portion of atmosphere exposed to the sun receives power to refract the lines of magnetic force which traverse it, and the whole of that which covers the darker hemisphere assumes an equally altered, but contrary state, relative to the mean condition of the air. It is as if the earth were inclosed within two enormous magnetic lenses competent to affect the direction of the lines of force passing through them.

2893. I have already said that the action of the atmosphere thus affected might in some degree be compared at night time to that of an enormous, diffuse, and very feeble ordinary magnet, having the position that it would naturally take according to the line of dip, passing over us from east to west, and including us for the time within its influence: in the daytime the action would be like that of the similar journey, not of a corresponding magnet reversed in direction, but of a corresponding globe of diamagnetic matter (2821.). Assuming the maximum heat and cold to occur at midday and midnight, we might expect that the maximum effects would also occur near those periods as regards the variations of intensity (2824. 2866.); for, other things being the same, the central parts of the heated and cooled masses are those where the difference of intensity should be greatest.

2894. It might be expected that this variation in the *intensity* would be greatest at those parts of the globe over which the sun passes vertically, or nearly so; but that may depend upon two circumstances at least; first, whether the difference in the day

* On the means adopted for determining the Absolute Values, Secular Change, and Annual Variation of the Magnetic Force, Philosophical Transactions, 1850, p. 201.

and night temperature is greater there than at other places, because the extent of the variation may be dependent in part upon that difference; and next, whether the amount of effect to be expected is the same for the same difference in number of degrees of temperature at every part of the scale (2886.). If the conducting power of oxygen (2800.) should be found by future experimental measurements (2960.) to increase in a greater proportion for a fall of a given number of degrees at lower temperature than at high ones (including the effect of contraction for that fall (2861.)), then it may be that parts more distant from the sun will be more affected than those under it; or if the contrary be the case, less affected than otherwise would be expected.

2895. With regard to the daily variations, as respects the *direction* of the lines of terrestrial magnetic force, or the inclination and declination of the magnetic needle, the principles of the changes that may be expected to occur have been already referred to (2879.); and it remains for me to compare these expectations with a few simple cases of observation, in such a general manner as will tend to show whether the *direction* of action is, both in theory and fact, the same; and whether there is any probability that the effect has been assigned to its true cause; for this purpose I will confine myself entirely at present to a part of the daily variation, namely, the effect of the sun and air as the luminary arrives at and passes over the meridian.

2896. Profiting by the last volume which has issued from the powerful mind and careful hands of Colonel Sabine*, I will take the case of Hobarton. The observatory there is in latitude 42° 52′·5 south, and longitude 147° 27′·5 east of Greenwich. The absolute declination is 9° 60′·8 east, and the dip is 70° 39′ south. In order to have the place of the sun and the time of maximum and minimum temperatures at hand, I have transferred the mean temperature for January (summer) for seven years, 1841–48, and the mean temperature for June (winter) for the same period, corresponding to every hour in the day and night, from pp. lxxxiv. and cviii. to fig. 10, Plate I., where the middle series of numbers represents the hours, the line next below them a base line of temperature at 30° Fahr., and the two curves still lower down the mean hourly temperature for summer and winter. The short lines show generally the direction of the needle east or west of its mean position, the upper end being of course the north extremity. The positions about noon are distinguished by full lines, being those required for more immediate illustration.

2897. The north end of the magnetic needle at Hobarton is most east at 2 o'clock, and most west about 21 o'clock. Being at the extreme west at the latter hour, it passes through the full range of variation, or to the extreme east in five hours, or by 2 o'clock, and then requires the remaining nineteen hours to return to the utmost west. The maximum east and west declination is at 2 and 21 o'clock for summer, and at 3 and 22 o'clock for winter. The vertical positions show at what hours the declination was 0, and correspond with Sabine's zero. From 21 to 2 o'clock the needle

* Magnetical and Meteorological Observations, Hobarton, vol. i. 1850.

passes from one extremity of its variation to the other, the north or upper end traveling in the reverse direction to the sun, so that it and the sun cross the meridian together in opposite directions, nearly about or a little before noon. About 2 o'clock the needle is arrested, and after that time returns west, following the sun. It will be proper to state, that the north end of the needle, the motion of which has just been described, is the end towards the equator, and also, the upper end of a dipping-needle at Hobarton. This distinction will receive more significance presently.

2898. Hence the cause which affects the needle appears to be far more powerful, and more concentrated in time when the sun is present than when he is away. In this there is accordance between the time of the effect and the time when the sun could exert most influence on those magnetic conditions of the atmosphere, which are for the present supposed to govern that effect.

2899. It will be seen by examination of fig. 10, that the time of maximum temperature is not when the sun is on the meridian, but two hours after it, both in summer and winter. But in reference to temperature and its effect on the magnetic condition of the air, and through that on the needle, it is not the local temperature which is supposed to influence the needle, but that which affects enormous masses of air, above as well as below, and of which the temperature at the spot, however important it may become when we can properly interpret it, gives us as yet little or no knowledge. Still there are some points on which temperature has a more direct bearing. Thus the amount of variation of temperature is in summer double what it is in winter, and the amount of variation in the declination increases in the same proportion (2890.). The minimum temperature in winter is later than in summer, and the extreme western declination of the needle is also later at the same period.

2900. The varying *direction* of the magnetic lines of the earth is made known to us by observations in two planes, one the horizontal plane, to which the position east and west is referred, constituting declination, and the other a vertical plane passing through the line of mean declination, and supplying observations of inclination. The direction of the line of force referred to this plane might change so as either to increase or diminish the inclination, and it does increase at some places for the same hour of local time for which it diminishes at others; thus it increases at Greenwich whilst it diminishes at St. Helena, which is nearly in the same meridian. At Hobarton it changes rapidly at the east and west extremes of the variation, *i. e.* about 2 and 21 o'clock. From noon it diminishes until about 3 o'clock; it then continues nearly the same in summer, when the variation is greatest until 18 or 19 o'clock, from that time it increases until about 22 o'clock, and is nearly a maximum from thence till noon. Hence it will be understood, that the inclination is generally greatest during the rapid journey of the north end of the needle from west to east between 21 and 2 o'clock, and least in the other or prolonged half of the journey; and though this is partly broken up in the night effect, to be considered hereafter, still as a general result it always appears.

2901. All this may be roughly represented by fig. 11 (2909.), in which E. W. represents the path of the sun between the tropics as he comes up with the hours 21^h, 22^h, &c. in his daily journey, and *e* the path described by the north or upper end of the needle, freely suspended at Hobarton, and therefore showing both declination and inclination, *i. e.* the whole direction. Looking down upon such a needle, its upper end will take the course indicated by the arrow, and its position at any given hour is shown sufficiently by the leading lines.

2902. This relation of the motion of the needle to that of the sun has long been known; it has great significance in relation to my hypothesis of the physical cause of these variations. As regards the part of the action which I am considering, it is as if the pole of a magnet came on with the sun, of like nature to the upper end of the Hobarton needle, and at first drives that end west. Towards 19 o'clock the tendency westward diminishes, but the tendency south increases. At 21 o'clock, the increase in the sun's power, acting not directly from the sun but from a region in the atmosphere beneath it, is not sufficient to compensate for his more unfavourable position; the earth's force brings the needle back as regards declination, and then it passes eastwards, but the southerly motion or inclination still increases; about 24 o'clock, or noon, the sun is as to east or west declination indifferent, but powerful in southern action, making the inclination then, or soon after, a maximum. Then as the sun goes west of the needle, its power in driving the pole behind it eastward, will increase for a time, whilst the power producing inclination will diminish, until at 2 or 3 o'clock the earth's force will regain preponderance as the sun's power diminishes by distance, and the needle will return towards its least dip and mean inclination.

2903. All this may be represented experimentally by carrying a magnetic pole north of the dipping-needle, so as to represent the place of the sun-heated air to Hobarton, provided that pole be of the same kind as the north or upper pole of the needle. I have already stated (2877. 2863.), that when a portion of air is heated in a field of magnetic power, it loses in magnetic conduction power, and if in association with air less heated deflects the lines, assuming the state which I have distinguished as that of diamagnetic conduction polarity; then presenting the very polarity, or rather the very inflection of the lines of force, which would affect the needle, as it is affected. As the sun rises and passes north of such a place as Hobarton, the atmosphere under his coming influence becomes more and more heated and expanded; and referring to the model globes of air (2864. 2877.), it is as if such a warm mass passed with the sun through all the regions of the equator, extending also far north and south of it; and having Hobarton within its influence, produced the effects there observed.

2904. In such a view one sees a reason for the short time occupied in the return of the needle from west to east as the sun passes immediately over its meridian, and for the long time during which it is passing from east to west as the influence of the

sun is slowly withdrawn, and then again slowly renewed during the remaining part of his journey, exception being made for the present of the paramagnetic effects due to cold.

2905. I will now consider the Toronto case of diurnal variation as it is presented to us in the volume of magnetical observations, issuing from the same authority and hands as the former volume*, and also in further observations down to 1848, sent to me by the kindness of Colonel SABINE. The position of the observatory is in lat. 43° 39′ 35″ N. and long. 79° 21′ 30″ W. The absolute declination is 1° 21′ 3″ W., and the mean or absolute dip is 75° 15′ N., so that as regards Hobarton it is on the other side of the equator, and nearly on the other side of the world. The result for the months of June and December are placed in a diagram corresponding to that for Hobarton (2896.), employing the Toronto time for the hours, Plate I. fig. 12.

2906. The north end of the needle is that universally referred to in speaking of the declination; its course at Toronto, during the immediate sun effect, is as follows:— Having gradually moved east from 16^h, it is at extreme east at 20 o'clock, and then returns from the east to extreme west in six hours, after which it moves eastward from the sun. But if we convert this into the motion of the equatorial extremity of the needle, for that is the *upper* end if the needle be free, and concerns us most in the comparison with Hobarton, then it will be seen that this end is most west at 19^h or 20^h; and leaving that position at that hour, it travels quickly eastward, passing through the full range of variation or to extreme east in six hours, or until 2^h, and then returns, following the sun.

2907. Looking at these results, I might repeat the words used in illustration of the Hobarton effects, but for the sake of brevity will simply refer to them. As before, the amount of variation in the declination is in summer double what it is in winter. The difference of temperature is three times greater. The extreme west and east declination is both in summer and winter at 20 and at 2 o'clock, so that the magnet holds to the time in both seasons; but the maxima and minima of cold, as shown before, vary in the two seasons, for the former is at 4 o'clock in summer and 2 in winter, whilst the latter is at 16 o'clock in summer, and 20 o'clock in winter. But this is a variation with consistency; for it will be seen by a moment's inspection, that in winter the maximum of heat has moved towards the time of most powerful action in the one direction, and the minimum has moved towards it in the other. The passage of the sun, therefore, over the meridian, and the period of rapid motion of the needle from west to east, still coincide.

2908. The other element of direction is the inclination. Its variation is very small, but changes thus. A principal maximum dip occurs at 22 o'clock, and the extreme minimum dip at 4 o'clock.

2909. So all the effects may again be generally represented by an ellipse (fig. 13)

* Magnetical and Meteorological Observations. Toronto, 1840, 1841, 1842, SABINE.

as they were for Hobarton; and I may refer to the words then used, substituting

Fig. 13.

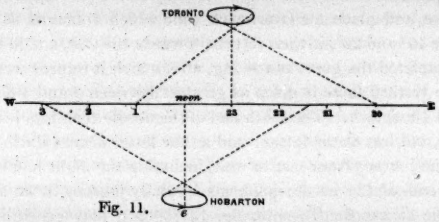


Fig. 11.

Toronto for Hobarton, and north for south (2901.). As the sun comes up from the east in his course between the two places, he drives, by the altered atmosphere beneath him, the upper ends of their needles before him, and outwards from the line of his path, as if he were a north pole to the Hobarton magnet, and a south pole to the Toronto magnet. By 22 o'clock, the earth's force, and the action of the air due to the sun's position, permit a return to the east, though the inclination for a time increases (2902.); both swing rapidly round from west to east as he passes over the meridian, and then having attained their maximum position eastward, soon follow after him under the influence of the earth's force, less and less counteracted by the retreating sun. So striking is the similarity between Hobarton and Toronto, that Colonel SABINE has already especially distinguished and described it*, and has shown, that, laying down the direction of motion in both cases by curves, and bringing the two curves together by their faces, they coincide almost exactly, with this single difference, that the Hobarton changes precede those at Toronto by an hour, or rather more, of local time.

2910. We cannot represent this day effect experimentally upon two such needles as those at Hobarton and Toronto by one pole of a magnet, though we can do it with each separately with different poles: but we see at once from the hypothesis, the reason why the sun acts in this manner (2877.), and how it is that the region of influential atmosphere that accompanies him in his journey round the globe, acts with one effect in the northern latitude and another in southern positions (2903.). The reasons also for the short time of the day journey and the lengthened period of the night return (2904.), are manifest. The occurrence of disturbances or secondary waves of power in the night time, and the condition both of the chief variation and the subordinate oscillations in summer and winter, will be considered hereafter.

2911. *Greenwich.*—The following results are taken from the volume of Greenwich Observations for 1847. The latitude is 51° 31′ N., and being removed nearly 80° in longitude from Toronto, the station is well contrasted with it and also with Hobarton.

* Hobarton Magnetical Observations, 1850, p. xxxv.

The mean declination is 22° 51′ 18″ W., and the mean inclination is 69° N. As it is the upper end of the dipping-needle which we have to consider for the purpose of a ready comparison with the sun's observed day action (2906.), I will describe that part of its course and place for Greenwich time which concerns us now. Moving westward before 19^h and 20^h, it then returns towards the east, and in six hours, or by 1^h or 2^h, has completed the great sun swing, after which it returns west, following the luminary. The vertical force is given as greatest between 3 and 4 o'clock, and least between 11 and 13 o'clock. The south end of the needle therefore is more upright at the former time and less at the latter; and as the latter occurs during the prolonged return part of the journey from east to west, including the night hours, so we perceive that the upper end of the needle performs its daily journey in an irregular closed curve, which the ellipse for Toronto, fig. 13 (2909.), may generally represent; it passes from east to west slowly during the night hours, approaching the equator at the same time, and then it returns from west to east with far greater rapidity, performing this part of its journey at a greater distance from the equator and nearer to the pole.

2912. *Washington, U.S.*—Latitude 38° 54′ N.; longitude 77° 2′ W.; the mean declination 1° 25′ W.; the mean dip 71° 20′ N. The south or upper end of the needle is in the morning at extreme west, about 20 to 22 o'clock, and at extreme east about 2 o'clock; it then returns slowly west, with the night action as in former cases, regaining extreme west at 20 to 22 o'clock. This is exactly the same movement for declination, in relation to the place of the sun, as for the former localities. I have not the variation of the dip, but theory would lead one to conclude that it is greatest between 22 and 2 o'clock, and least in the evening and night time. The total amount of declination variation is greatest in summer, as before, being 9′·87 in July and only 4′ in December. The greatest difference in the earth's temperature is also in July, being then nearly 20° Fahr., whereas in December and January it is only 10° Fahr. The shortest period between the extreme temperature, including therefore the quickest change of temperature, is from 16 or 18 to 2 o'clock, and consequently includes noon. All these conditions combine to produce the greatest magnetic action, and it is in the direction pointed out by the hypothesis.

2913. *Lake Athabasca.*—Latitude 58° 41′ N.; longitude 111° 18′ W. of Greenwich; mean declination 28° E. The observations are only for five months, but as the position is in a high latitude and may be important for future considerations, I give the results here. The extreme western position of the upper end of the needle is about 17 or 18 o'clock, and its extreme eastern position about 1 or 2 o'clock; so that, as far as declination is concerned, the action of the sun and atmosphere is as in former cases. The amount of declination variation is very great, being in October 21′·32; in November 10′·8; in December 9′·78; in January 16′·29, and in February 14′·87.

2914. *Fort Simpson.*—Latitude 61° 52′ N.; longitude 121° 30′ W. of Greenwich;

mean declination 38° E. These observations are only for two months, *i. e.* April and May 1844. The extreme western place of the upper or south end of the needle was at 19 o'clock, and its extreme eastern position at 2 o'clock. The result therefore is in perfect accordance with the preceding observations and conclusions. The amount of variation, as given in the horizontal plane, is very large, being 36′·26 in April and 32′ in May.

2915. *St. Petersburgh.*—Latitude 59° 57′ N.; longitude 30° 15′ E. of Greenwich; mean declination 6° 10′ W.; the dip 70° 30′ N. The observations are the mean of six years, and show that the upper end of the needle is extreme west in regard of noon, about 19^h and 20^h for the months of March to August, and that for the other months there is a western position about the same hours. The extreme east position is, for *all* the months, about half-past 1 o'clock, so that the sun's effect in passing over at the noon period is as in former cases. The greatest amount of variation is 11′·52 in June; in winter it dwindles away to as little as 1′·77. From theory, the dip may be expected to increase during the day hours and diminish at night.

2916. Thus these cases, which, including the chief feature of diurnal variation and sun action, were selected as a first and trial-test of the hypothesis, join their evidence together, as far as they go, in favour of that view which I am offering for their cause; nor have I yet found any instance of even an apparent contradiction in regard to the sun action. They assist the mind greatly in forming a precise notion of the manner in which the influence of the sun and air is supposed to act, not only in similar cases, but in respect of other consequences, *i. e.* in all that properly comes under the term of atmospheric magnetism; I will therefore now restate more particularly the principles which, according to the hypothesis, govern them, in hopes that I may be fortunate enough to assist in developing by degrees the *true physical cause* of the magnetic variations in question.

2917. Space, void of matter, admits of the transmission of the magnetic force through it (2787. 2851.). Paramagnetic and diamagnetic bodies either increase or diminish the degree in which the transmission takes place (2789.). This, their influence, I have expressed, for the time, by the phrase of magnetic conducting power, and I think have given sufficient first experimental evidence of the existence of the power and its effects in disturbing the lines of magnetic force (2843.). The atmosphere is, by the oxygen it contains (2861. 2863.), a paramagnetic medium, and has its conducting force greatly diminished by elevation of temperature (2856.) and by rarefaction (2782. 2783.), as has also been fully proved by experiment. The sun is an agent which both heats and rarefies the atmosphere, and in its diurnal course, the place of greatest heat and rarefaction must, speaking generally, be beneath it. The irregularities in the condition of the earth's surface and other causes do produce local departures from an exact relation of place, but they probably disappear partly, if not altogether, in the upper regions of the air.

2918. Assuming that *the air under the sun* is most changed magnetically, and con-

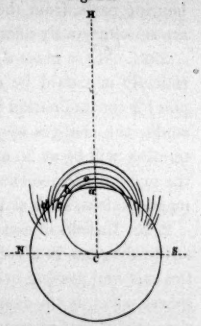
fining the attention to a spot where the sun is vertical, for the purpose of considering the condition of the atmosphere there and at other parts in relation to it, the supposition of a globe of air over the spot will of course find no fit application (2877.). We are first to suppose the sun far away and the atmosphere in a mean state as to temperature, and then consider the sun as present in the meridian of a given place; and it is *the degree of alteration* in temperature and expansion of the air beneath and around the place of the sun, and the manner in which the change comes on and passes away, which concerns us. In relation to the surface of the earth, that alteration will be greatest somewhere beneath the sun, and will diminish in every direction around, becoming nearly nothing as to direct action at that part or circle of the earth where the sun's rays are tangent. In relation to elevation, it is a question yet whether the effect is greatest in amount at the surface, diminishing upwards. As regards the atmosphere, it must of course end with it, though as respects space itself (2851.), a reservation thought may arise. With regard to any alteration occasioned by the sun's influence in the opposite hemisphere, though there is none produced directly, yet indirectly there is that due to the falling of the temperature of the air, from the condition to which the sun, whilst above the horizon, had brought it. This change must be more tardy, irregular and disturbed, by local and other circumstances, than the opposite alterations produced by the direct influence of the luminary, and is that which occasions, by the hypothesis, the second maximum or minimum or other recurring night actions, made manifest by the needle in the hours when the sun is away.

2919. The lines of force which issue from a magnet are, as it were, located and fixed by their roots in a way well understood experimentally by those who have worked upon this subject. In the same manner the lines which issue from the earth more or less suddenly, according to the amount of inclination, are held beneath by a force of location; and because of the unchanging action of the earth in respect of atmospheric effect, are restrained more or less from alteration beneath during the changing action of the atmosphere. This fixation in the earth is a chief cause of certain peculiarities in the atmospheric phenomena as we observe them; and is productive of that rotation of the line of force about the mean position which we have already considered during the sun swing, and shall meet with again under the action of cold air. This condition of fixation at the lower parts of the lines of force occurs at every station where there is any dip at all, and gives for each the point of convergence round which the motion of the upper end of the needle takes place (2909. 2932.).

2920. So the atmosphere, under the influence of the sun, lies upon the earth altered most at the part beneath the luminary. It has received power to affect the lines of magnetic force differently to the manner in which it affected them in the sun's absence. It has become a great magnetic lens, able to refract the lines, and the manner in which it does so appears to be of the following nature. All the lines passing through this heated and expanded air, surrounded by other air not so much

heated, will, because of its being a worse magnetic conductor than the latter (2861. 2862.), tend to open out (2807.); and the mass of heated air, as a whole, will assume the condition of diamagnetic polarity. If, therefore, for the sake of simplicity, the magnetic and astronomical poles of our earth be supposed as coincident, and fig. 14 represent a section taken through them and the place of the sun, then N and S will be the magnetic poles, and the different curves cutting the outline of the circle will sufficiently represent the course of the magnetic lines as they occur at or about the surface of the earth, H being the sun, and *a* the place immediately beneath it, which is also coincident with the magnetic equator. By this diagram we shall have an illustration of the hypothetical effect on the inclination of the needle.

Fig. 14.



2921. Considering the point *a* first, and assuming as yet that the maximum of change in the air is always at the surface of the earth, we shall find that there the lines of force will open out, preserving in some degree their parallel or concentric relation. Consequently a magnetic needle, free to move in every direction, and therefore taking up its position *in* the line of force, ought not, if placed at this spot, to be altered in its position. It ought to show perhaps a diminution of magnetic force transmitted through that spot; but, for the reason before given (2868.), I conclude it would indicate a greater intensity, the increased power thrown upon it through the diminution of the conducting power of the air in that place causing it to act as a more powerful needle.

2922. Proceeding to a point *b*, there the lines of force have dip. The same physical effect will be produced upon them here as before, *i. e.* the portions in the atmosphere will open out; but neither here nor in the former case will they continue to have the same curvature as before, for towards and in the earth, where they have their origin, they are restrained more or less from altering by the unchanging action of the earth (2919.); whilst at their more advanced parts, as at *c*, they enter into portions of the atmosphere which are nearer to the most intense lines of solar action, H C, probably also into the region of most intense action, and also into space, circumstances which cause more displacement of the lines, tending to separate by the tension of the parts altered in the air, than can happen *in* the earth (2848.). So the magnetic line of force at *b* will not move parallel to itself, but being inclined a certain degree to the horizon, when in the normal condition, will be more inclined, *i. e.* will have more dip given to it by the presence of the sun. This is the fact made manifest by the needle when indicating the position of the line as to inclination (2908.) at Hobarton, Toronto or elsewhere, by the motion of its upper end; for it is manifest that whatever happens on one side of the place of the sun and magnetic equator, when, as in our supposition (2920.), they coincide, will happen on the other.

2923. The case may be more simply stated, for the facility of recollection, by saying that the effect of the sun is to raise the magnetic curves, over the equatorial and neighbouring parts, from their normal position, in doing which the north and south dip are simultaneously affected and increased.

2924. At the place *d* like effects on the inclination must be produced, and theoretically it should be affected in the same direction even at N. and S. At the point *a* the inclination is supposed to be not at all altered, but going either north or south, the changes appear and increase. It is not probable that the maximum alteration will be at N. or S., but the latitude where it will occur must depend upon the many conjoined circumstances that belong to the case of a globe round which a magnetic lens, such as I have endeavoured to describe, is continually revolving.

2925. Instead of assuming that the sun is at H, let us suppose that we are looking at the diagram in a vertical position and towards the east; the sun coming up from the east and passing over our heads, and bringing with it that condition of our atmosphere which is the cause of the change. As it does so, all the magnetic curves would rise; the inclination would increase at *b*, *d*, and every place where there was any beforehand, in opposite directions on the two sides of *a*; this would go on until the sun was in the zenith, and then as it passed away and sank behind us, the lines would draw in again and the dip diminish to what it was at first. The maximum of dip would be when the sun was near the zenith, and the minimum when he was quite away.

2926. But if the resultant of force be above in the atmosphere (2937.), which is by far the most probable, as it is the whole atmosphere which acts by heat diamagnetically, then the results would be modified; for if over *a* the lines of force might be *depressed*, and the inclination there would be diminished; at *b* it might not for the moment be affected; whilst in higher latitudes it would be increased, according as the line of force from the resultant in the atmosphere, wherever that might be, fell outside of the angle formed by the inclination with the horizon of a given place or within it. St. Helena, the Cape of Good Hope and Hobarton, furnish instances of the three cases.

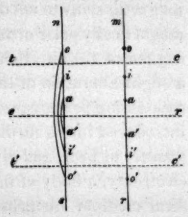
2927. At the same time the total force would undergo a change in its amount; that transmitted through a given space would be least when the sun was in the zenith, and most when he was away (2863.). The total variation in the force should be greatest at *a*, and diminish from thence towards north and south. The daily variations of the inclination are so imperfectly known to us at present, that we cannot say how far the natural changes will accord with these expected variations, but as far as the observations go they agree with the theory.

2928. If the sun, instead of being over the equator, is at a tropic and so vertical, for instance over *b*, then the effects will be modified; and the resultant still being assumed as above, the lines of force which before were not affected, may be expected to descend and lessen the inclination, whilst other lines in higher latitudes, which before were increased in inclination, may now be but little affected, and other lines

in still higher latitudes have, as before their inclination, increased. On the other side of the equator, the tendency of the lines would be to increase in inclination.

2929. Proceeding to that part of the expected change of position of the free needle which produces variations of *declination*, let $e\ r$ in fig. 15 represent the sun's path in the equator, and $t\ c$, $t'\ c'$ the same at the tropics; let $m\ r$ be a magnetic meridian, and $a\ a'$, $i\ i'$, $o\ o'$ places of equal north and south inclination on opposite sides of the equator. The curves of magnetic force seen in front in fig. 14, are now in the plane of the magnetic meridian, but may be considered as rising on opposite sides of the equator and coalescing over it. If the air on all sides were in its mean condition and the sun entirely away, these curves would be in the vertical plane $m\ r$; or if the sun near midday was so placed that the resultant of the heated and changed atmosphere was in the meridian $m\ r$, though effects of inclination would occur (2922.), still the curves would remain in the same vertical plane. But if the resultant were either to the east or the west of $m\ r$, variations of declination would be produced. For suppose the sun to be advancing from the east or r; because it gives the air a diamagnetic condition, the lines of force would tend to expand (2877.), and therefore move westward, as represented in the meridian $n\ s$; and the deflection caused thereby would be greatest upon the surface of the earth, because it is there that the curves as they enter the earth are held and restrained in respect of their normal position (2919.). As the warmed atmosphere came on, the western deflection would increase to a certain extent, and then diminish to nothing when the resultant was in the meridian; but as the latter passed on, the deflection would grow up on the eastern side of $n\ s$, and, after attaining a maximum, would diminish and cease as the warm air retreated.

Fig. 15.



2930. If the sun's path was in the northern tropic, $t\ c$, and the resultant in the atmosphere therefore to the north of the stations a or i, though that would make a difference in the amount of the declination variation, it would not alter its *direction*, for still the curves $a\ a'$ and $i\ i'$ would bear to the west as the sun came up, and would be on the meridian when the resultant was there also. There would be more effect produced at i than at i', but the contrary character of the dip, in respect of the sun's place, would not alter the direction of the declination variation.

2931. A cold region of air acting, as at the coming on of night, upon the lines of magnetic force of the earth, would, by virtue of its paramagnetic character (2865.), produce corresponding effects both of inclination and declination, but in the contrary direction.

2932. Thus the lines of force which issue from the earth at all places upon its surface where there is any dip, will, by the hypothesis, under the daily influence of the sun, describe by their ascending parts a closed curve or irregular cone, the apex of which is below. As a fact this result is perfectly well known, but its accordance with the hypothesis is important for the latter. The mean position of the free needle will

be in the axis of this curve or cone, and its return, either in declination or inclination, to the mean is an important indication of the amount and position of the variable forces which influence it at such times.

2933. My hypothesis does not at all assume that the heated or cooled air has become magnetic so as to act directly on the needle after the manner of a piece of iron, either magnetically polar or rendered so under induction. There is no assumed polarity of the oxygen of the air other than the conduction polarity (2822. 2835.) consequent upon a slight alteration of the direction of the lines of force. The change in the magnetic conducting power causes this deflection of the lines; just as a worse conductor of heat introduced into a medium of better conducting power disturbs the previous equable transfer of heat, and gives a new direction to that which is conducted; or as in static electricity, a body of more or less specific inductive capacity introduced into a uniform medium disturbs the equable lines of force which were previously passing across it.

2934. The sole action of the atmosphere is to bend the lines of force. The needle being held by these lines and, when free, being parallel to them, changes in position with the changes of the lines. It is not necessary even that the lines, which are immediately affected in direction by the altered air, should be those about the needle, but may be very distant. The whole of the magnetic lines about the earth are held by their mutual tension in one connected sensitive system, which has no sluggishness anywhere, but feels in every part a change in any one particular place. There may be, and is continually, a new distribution of force, but no suppression. So when any change in direction happens, near or distant, the needle in a given place will feel and indicate it, and that the more sensibly according to the vicinity of the place and the kind of change induced; but the disposition of the *whole* system has been affected at the same moment, and therefore all the other needles will be affected in obedience to the change in the lines of force which govern them individually.

2935. The needle is a balance on which all the magnetic power around a given locality fastens itself, even to the antipodes, and it shows for each place every variation in their amount or disposition, whether that occurs near or far off. Its mean position is the normal position; and as regards atmospheric changes, the fixation of the lines of force in the earth (2919.) is that which tends to give the lines a standard position (exclusive of secular changes), and so bring them and the needle back from their disturbed to their normal state. Hence, whilst considering the causes which disturb either the declination or the inclination, arises the importance of keeping in mind the mean position or place of the needle (2932.), and not merely the direction in which it is moving.

2936. So the well-known action of the sun on the needle is, by my hypothesis, very indirect; the sun at a given place affects the atmosphere; the atmosphere affects the direction of the lines of force; the lines of force there affect those at any distance, and these affect the needles which they respectively govern.

2937. I have, for the sake of convenience in considering a special action of the

atmosphere, spoken of the resultant in the atmosphere dependent on the sun's presence; and will do so a little while longer without implying any direct action of this resultant, or that portion of air which yields it, upon the needle (2933.), for the sake of considering at what probable height it is situated in the air. That it cannot be on the surface of the earth, is shown by the depression of the lines and diminution of the dip at St. Helena and Singapore during the middle of the day; and that it is not even under the sun, is shown by the manner in which the greatest action precedes, in some degree, the sun, as at Hobarton and Toronto, and other places by different amounts of time; neither the time when the sun is on the meridian, nor the time when the observed temperature is highest (for that is after the sun), is the time of greatest action, but one before either of these periods. The changes in the temperature of the air produced by the sun, will not take place below and above at the same time. The upper regions of the atmosphere over a given spot are affected by the sun at his rising and afterwards, before the air below is heated; and therefore the effect from above would be expected to precede that below. The temperature observed on the earth does not show us, for the same time, the course of the changes above, and may be a very imperfect indication of them. The maximum temperature below is often two, three, or four hours after the sun, whereas, whatever heat the sun gives by his rays directly to the atmosphere, must be acquired far more rapidly than that. It is very probable, and almost certain, that at 4 or 5 o'clock A.M. in the summer months, the upper regions may be rising in temperature, whilst on the surface of the earth, through radiation and other causes, it is falling. The well-known effect of cold just before sunrise in some parts of India, and even in our country, is in favour of such a supposition. We must remember that it is not the absolute temperature of the air at any spot that renders it influential in producing magnetic variations, but the *differences* of temperature between it and surrounding regions. Though the upper regions be colder than the lower, their changes may be as great or greater; they happen at a range of temperature which is probably more influential than a higher range (2967.); and, what is of importance, they occur more quickly and directly upon the presence of the sun. The quantity of heat which the atmosphere can take directly from the sun's rays, is indicated by the different proportions we receive from him when he is either vertical or oblique to us, and so sending his beams through less or more air; and when he has departed, the upper parts of the air are far more favourably circumstanced for rapid cooling by radiation than the portions below. So that the final changes may be as great or greater than below, and we may learn little of them, or their order, or time, by observations of temperature at the earth's surface. In addition therefore to observations of magnetic effect, as depression of the lines of force at St. Helena, &c., there are apparently reasons deducible from physical causes, why the chief seat of action should be above in the atmosphere.

2938. In the midday effect the upper end of the needle passes the mean position

(2935.) on its return to the east generally before the sun passes the meridian going westward. At Toronto it is about an hour in advance; at St. Helena and Washington an hour and a half; at Greenwich and Petersburgh two hours; at Hobarton and the Cape of Good Hope the passage is about noon. Such results appear to indicate that the place of maximum action is in advance of the sun; and it probably is so in some degree, but not so much as at first may be supposed, as will appear I think from the following considerations.

2939. The precession of the time of maximum action may depend in part upon some such condition as the following. As the sun advances towards and passes over a meridian, the air is first raised in temperature and then allowed to fall, and these actions produce the differences in different places on which the magnetic variations depend. But they depend also upon the *suddenness* with which or the vicinity at which these differences occur. Thus two masses of air, having equal differences of temperature, will affect the lines of force more if they be near together, and to the needle, than if they be far apart. And again, if a body of air were of a certain low temperature at one part, and, proceeding horizontally, were to increase rapidly to a certain high temperature and then diminish slowly to the first low temperature, such a body passing across a set of lines of magnetic force would affect them in opposite directions at the fore and after part; but it would affect them most on the rapidly altering side.

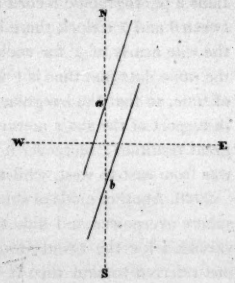
2940. Now the air as heated by the sun must be in this condition. According to analogy with solid and liquid bodies, being exposed to heat and then withdrawn, the changes of temperature that it would undergo would be more rapid in the elevation than in the falling, and so the changes in the preceding would be more rapid than in the following parts. To this would be added the effect of the atmosphere warmed by the earth; for as that is slower in attaining heat, as is shown by the time of maximum temperature, so its effects being gradually communicated to the air above, as the sun passed away, would tend to retard its fall and enlarge the difference already spoken of. Applying these considerations to the natural case, the strongest effect and the greatest variation should be towards the west, and the following or lesser action towards the east of the sun; and the mean condition of the needle for the whole change would be in advance of that body.

2941. Mr. Broun has made observations of the daily variation at different heights, namely, at Makerstoun and the top of the Cheviot Hills, where the height differs by nearly half a mile, and finds, I believe, no difference in the intensity, but that the progress is *first* at the higher station. It would be very interesting to have an observatory up above, but to give the results required it should have air and not solid matter beneath it.

2942. There is another circumstance which importantly influences the *times* of the passages of the declination variation. If two places north and south of the equator have equal dip and contrary declinations, *i. e.* if both their upper ends point east or west, then the effects ought to correspond and form a pair. But if both have east or west

declination, according to the usual mode of marking this effect by the north end of the magnet, then the variations already described should come on as the sun passes midway between them, but there should be a difference in *time*. As the luminary appears and approaches, the needles *a* and *b* (fig. 16) will most probably be affected together; but, as he draws nigh, if the places have eastern declination, the one that is south will be soonest affected, and for the time most strongly, but will in a period more or less extended, be followed by the corresponding action at the other place. For as each needle will have returned from the first half of its series of changes to 0° by the time the sun is on its magnetic meridian, and as it will arrive at this meridian, as regards the south needle, before it does so for the north needle, so the south magnet should precede the other in its changes. If the declination of both were westerly, then the north needle would precede the south.

Fig. 16.



2943. The hypothesis advanced, besides agreeing with the facts regarding the direction of the needle's motions, as is the case generally, and if my hopes are well-founded, will be the case also in more careful comparisons; should also agree in the *amount* of force required for the observed declinations at given hours. I have endeavoured to obtain experimental evidence of the difference of action of oxygen and nitrogen on needles subjected to the earth's power, but have not yet succeeded. This however is not surprising, since a saturated solution of protosulphate of iron has failed under the same circumstances. More delicate apparatus may perhaps yield a positive result.

2944. That small masses of oxygen should not give an indication of that which is shown by the atmosphere as a whole is not surprising, if we consider that the mass of air is exceeding great, and includes a vast extent of the curves on which it, by the hypothesis, acts; and yet that the effect to be accounted for is exceeding small. The extreme declination at Greenwich is 12′, equal to about 4′ 24″ of east and west alteration on the free needle, so that that is the whole of what has to be accounted for. One could scarcely expect such an effect to be shown by small masses of oxygen and nitrogen acting on only a few inches in length of the magnetic curves passing through them, unless one could use an apparatus of extreme and almost infinite sensibility; but from what I have seen of oxygen when compared at different degrees of dilution (2780.), or at different temperatures (2861.), I am led to believe that the effects on it produced by the sun in the atmosphere will ultimately be found competent to produce these variations.

2945. Where the air is changed in temperature or volume, there it acts and there it alters the directions of the lines of force; and these by their tension carry on the effect to more distant lines (2934.), whose needles are accordingly affected. The transferred effect will be greater or less according as the distances are less or greater, and

hence a change near at hand may overpower that at a distance, and a cloud close to a station may for the moment do more than the rising sun. These are the irregular variations; and the extent of their influence is well shown by the photographic records of Greenwich and Toronto. The volume of Greenwich Observations for 1847 contains a photographic record of the declination changes, February 18—19, 1849. Between 6 and 7 o'clock there is a variation of 16′ occurring in 18 minutes of time, or at the rate nearly of 1′ for each minute of time. The course of the mean variation for the same date and time is 1′·95 in two hours, or at the rate of 1 second for each minute of time, so that the irregular variation (which may be considered as a local variation in respect of the sun's power for the time) is sixty times that due to the effect of the great resultant; moreover it was in the reverse direction, for the temporary variation was from east to west, whilst the mean variation was from west to east.

2946. Another mode of showing how much the action of nearer portions of the atmosphere overpower and hide the effect of the whole mass, is to draw the line of mean variation for the twenty-four hours through such a photographic record as that just referred to, and then it will be seen in every part of the course how small the mean effect on the needle is, compared to the irregular or comparatively local effect for the same moment of time. The magnet with which these observations were made, is a bar of steel 2 feet long, $1\frac{1}{2}$ inch broad and a quarter of an inch thick, and therefore not obedient to sudden impulses; it is probable that a short, quick magnet would show numerous cases in which the irregular variation would be several hundred of times greater than the mean. Still all these irregularities and overpowering influences of near masses are eliminated by taking the mean of several years' observation, and thus a true result is obtained, to which the hypothesis advanced may be applied and so tested.

2947. Returning for a short time to the annual variation (2882.), I may observe, that it has been a good deal considered in discussing the daily variation. The arrangement of the magnetic effects by Colonel SABINE at Hobarton, Toronto, St. Helena and elsewhere, into monthly portions, proves exceedingly instructive and important, especially for places between and near the tropics. It supplies that kind of analysis of the annual variation which is given by the hours for the daily variation. Every month, by a comparison of its curve with those of other months, tells its own story, at the same time that it links its predecessor and successor together.

2948. I shall have occasion to trace these monthly means hereafter; but in the meantime refer to the effect of the sun's annual approach and recession indicated by these means, as according with the hypothesis in respect of near and distant actions (2945.). Hobarton and Toronto are in opposite hemispheres, so that the sun whilst approaching one recedes from the other, and the amount of variations therefore changes in opposite directions. Below is the average for each month, derived in the case of Hobarton from a mean of seven years, and in that of Toronto from a mean of two years.

	Hobarton. Lat 42° 52′·5 S.		Toronto. Lat. 43° 39′·35 N.	
January	11′·66		6′·51	
February	11·80		6·40	
March	9·50		8·50	
April	7·26		9·52	
May	4·56		10·34	
June	3·70	Winter.	11·99	
July	4·61		12·70	Summer.
August	5·89		12·68	
September	8·24		9·72	
October	11·01		7·59	
November	12·05	Summer	5·75	
December	11·81		4·47	Winter.

The two stations are in latitudes differing only 47′ from each other; and the extreme difference of the atmospheric effect between summer and winter differs as little, being at one, Hobarton, which has the highest latitude, 8′·35, and at Toronto 8′·23.

2949. According to Dove, the northern hemisphere is warmer in July than the southern hemisphere by 17°·4 Fahr., and colder in winter by only 10°·7; the numbers being as follows:—

July.	Northern hemisphere 71°·0 Southern hemisphere 53·6	62°·3	the whole globe.
January.	Northern hemisphere 48·8 Southern hemisphere 59·5	54°·15	the whole globe.

The mean for the whole year is 59°·9 for the northern hemisphere, and 56°·5 for the southern. Therefore, as Dove further shows, the whole earth is in July, when the sun is shining over the terraqueous parts, 8° higher in temperature than in January, when it is over the watery regions: and from the influence of the same cause, the mean of the southern hemisphere is 3°·4 below the mean of the northern half of the globe. The difference between January and July is for the northern hemisphere 22°·2, and for the southern only 5°·9. These differences are so peculiar in their arrangement and so large in amount, that they must have an effect upon the distribution of the magnetic forces of the earth, but the data are not yet sufficient to enable one to trace the results. Sabine indicates a probability from his analysis of observations, that the sum of the earth's magnetic force is increased in intensity when the sun is in the southern signs, *i. e.* in our winter (2891.). I should have expected from theory that such results would have been the case, at least in those parts where the dip was not very great; because a colder atmosphere ought to conduct the lines of magnetic force better, and therefore the systems round the earth ought at such a time to condense, as it were, in the cooler parts. It would be doubtful, however, whether the needle would show this difference, because the lines of power would

not be restrained above, as in the case formerly supposed (2922.), but could gather in from space freely. From what has been said, however, it will be evident that such a conclusion can only be drawn with any degree of confidence from observations made pretty equally over both hemispheres.

2950. If we should ever attain a good knowledge of the annual variation for several stations in different parts of both hemispheres, it would help to give data by which the depth at which the magnetic power is virtually situated might be estimated; for, as this power is expected to undergo undulations over very large portions of the earth's surface by the annual changes of temperature (2884.), so they would differ in character and extent according as the origin of the lines should prove to be more or less deeply situated.

2951. With regard to the many variations of magnetic force, not periodic or not so in relation to the sun, which yet produce the irregular and overruling changes already referred to (2945.), dependent, as I suppose, on local variations of the atmosphere, I may be allowed to notice briefly such points as have occurred to my mind.

2952. The *varying pressure* of the atmosphere, over a given part of the earth's surface, ought to cause a variation in the magnetic condition of that part of the earth. It is represented to us by a difference of three inches of mercury, or one-tenth of the weight of the atmosphere. Now the oxygen in a given space is paramagnetic in proportion to its quantity (2780.), and therefore it does not seem possible that that quantity over a given space of the earth's surface, whether it be recognised by volume as above, or by weight as in a given volume at the earth's surface, should be varied to the extent of one-tenth of the whole sum without producing a corresponding alteration in the distribution of the magnetic force; the lines being drawn together and the force made more intense by an increase of the quantity or of the barometric pressure, and the reverse effects produced at the occurrence of diminished pressure.

2953. At any spot which is towards the confines of that space where the air is increasing or diminishing in pressure, there will probably occur variations in the directions of the lines of force, and these will be more marked at such places as happen to be between two others, in one of which atmosphere is accumulating, whilst from the other it is retreating. Whether these changes (which I think must occur) produce by vicinity effects large enough to become sensible in our magnetic instruments, is a question to be resolved hereafter. To suggest the cause is useful, because to know of the existence, nature, and action of a cause, is important to the arrangement of the best means of observing and evolving its effects.

2954. *Winds and large currents of air above* may often be accompanied by magnetic changes if they endure for a time only. A constant stream like the trade-wind, may have a constant effect; but if, when the arrangement of the lines of magnetic force through the atmosphere is in a given state consequent upon the condition of the atmosphere at that time, a wind arises which mixes regions of cold and warm

air together, or makes the air more dense in one region than another, or proceeding from one to another, balances regions which before were in different conditions, then every such change will be accompanied by a corresponding change in the disposition of the magnetic force, to which we may perhaps hereafter be able to refer by means of our instruments. Even tides in the air ought to produce an effect, though it may be far too small to be rendered sensible.

2955. The precipitation of *rain or snow* is a theoretical reason for the change of magnetic relations in the space where it takes place; because it alters the temperature where such precipitation occurs, and relieves it from a quantity of diluting diamagnetic or neutral matter. A *chilling hail-storm might* affect the needle in a summer's day. *Clouds* may have a sensible influence in several ways; acting at one time by their difference from neighbouring regions of clear air, and at other times by absorbing the sun's rays, and causing the evolution of sensible heat at different altitudes in the atmosphere at different places, or preventing its evolution more or less at the surface of the earth. Those masses of warmer or colder air of which meteorologists speak, which being transparent are not sensible to the eye, will produce their proportionate effect. And hypothetically speaking, it is not absolutely impossible that the hot and partially deoxygenated air of a large town like London, may affect instruments in its vicinity; and if so, it will affect them differently at different times, according to the direction of the wind.

2956. If one imagines on the surface of the earth a spot which shall represent the resultant there of the atmospheric actions above, and can conceive its course as it wanders to and fro, under the influence of the various causes of action which have been in part referred to, whilst it still travels onwards with the sun, one may have an idea of the manner in which it may affect the various observatories scattered over the earth. I believe that its course, as regards the east and west direction of its wanderings, is partly told in the photographic registerings of Greenwich and Toronto, being there mingled in effect with other causes of variation. This spot may be concentrated or diffuse; it may pass away and reappear elsewhere; there may even be two or more at once sufficiently strong to cause vibrations of the needle between them.

2957. The aurora borealis or australis can hardly be independent of the magnetic constitution of the atmosphere, occurring as it does within its regions, and perhaps in the space above. The place of the aurora is generally in those latitudes the air of which has a distinct magnetic relation, by difference of temperature and quantity, to that at the equator, and the magnetic character both of the aurora and of the medium in which it occurs ties them together; therefore, to be aware of and to understand in some degree the latter, will probably direct us to a better comprehension of the former. The aurora is already connected with magnetic disturbances and storms; it may in time connect them with changes in the atmosphere in a manner not at present anticipated, and as the suggestion is founded upon principle it seems deserving of consideration.

2958. Can the magnetic storms of HUMBOLDT be due to atmospheric changes? This is a question on which I would offer the following observations. Supposing a magnetic rest in the atmosphere, and that all local or irregular variations remained unchanged for the time, then if a change happened in one place it would be felt instantly everywhere else over the whole earth, and in proportion to the distance from the place of change. It would be felt instantly, because the impulse would not be conveyed chiefly or importantly through the matter of the earth or air, but through the space above, for the lines there are affected by changes in that part of them which passes through the atmosphere, and, as I conceive, would affect the other lines in space round our globe, which would in turn affect those parts of their lines, which, passing downwards to the earth, govern the needles below. In space, I conceive that the magnetic lines of force, not being dependent on or associated with matter (2787. 2917.), would have their changes transmitted with the velocity of light, or even with that higher velocity or instantaneity which we suppose to belong to the lines of gravitating force, and if so, then a magnetic disturbance at one place would be felt instantaneously over the whole globe.

2959. But the difficulty is to conceive an atmospheric change sufficiently extensive and sudden to make itself perceived everywhere at the same time amongst the comparatively local variations that are continually occurring. Still, if there were a lull in these disturbances by the opposition of contrary actions or otherwise for the same moment of time at two or more places, those places might show a simultaneous effect of disturbance, and that even when the cause might be very little or not at all sensible in the place where it occurred. A simultaneous change over an area of 600 or 800 miles in diameter, might produce less alteration in the middle of that area than at the extremities of radii of 1000 miles.

2960. It becomes a fair question of principle to inquire how far masses of the air may be *moved* by the power of the magnetic force which pervades them. When two bulbs of oxygen in different states of density are subjected to a powerful magnet with an intense field of force, the mechanical displacement of one by the other is most striking. Whether in nature the enormous volumes of air concerned, and the difference in intensity of the earth's magnetic force at the different latitudes where these may be supposed to be located, combined with the difference of temperature, are sufficient to compensate for the small portions of oxygen in the air and the smaller variations in density, is a matter that cannot at present be determined. The differential result of motion, as has been shown, is very great where the direct result, as of compression, is not merely very small but nothing (2774. 2750.), and the atmosphere is a region where the differential action of enormous masses is concerned.

2961. Now in the matter of difference of intensity, GAY-LUSSAC and BIOT conclude from their observations*, that the magnetic force is the same at a height of four miles as at the surface of the earth. M. KUPFFER, however, draws from GAY-LUSSAC's

* Annales de Chimie, An. xiii. vol. lii. p. 86.

results the conclusion, that there was a little diminution, and Professor FORBES, from his experiments made in different parts of Europe*, concludes that there is a decrease of the force upwards. Such decrease may be a real consequence due to the difference of distance from the source of the terrestrial magnetic force; or, as is more likely, it may be due to the different proportions of oxygen there and at the surface of the earth. According to GAY-LUSSAC's account of the air brought from above, it was as 0·5 to 1·0, compared with the density below. Hence the paramagnetic power, added to space in the place above, from whence the air was taken, would not be more than one-half of that added by the presence of the denser atmosphere below. This I think ought to make a change in the distribution of the magnetic force; it would almost certainly do so at the equator, where the lines of force are parallel to the general direction of the atmosphere (2881.); and I think it would do so, as to the horizontal component, in the latitude where GAY-LUSSAC and BIOT made their aërial voyages. It is also just possible that the observers may have been in such relation to the heated or cooled air about them as to have had the difference observed produced, or rather affected, by some of the circumstances just described (2951.).

2962. Whether the result obtained by GAY-LUSSAC and BIOT indicate a change of power due to distance or not, this we know, that there *are* great changes from the magnetic equator toward the north and south; and that, as HUMBOLDT and BESSEL say, it is doubled in proceeding from the equator to the western limits of Baffin's Bay. And when so little as one-third of a cubic inch of oxygen can exert a force equal to the tenth of a grain, subject to the action of our powerful magnet, we may well conceive that the enormous sum of oxygen present, in only a few miles of heated or cooled atmosphere, can compensate for the great difference of magnetic force, and so, by a change of place, cause currents or winds having their origin in magnetic power. In such a case we should have a relation of magnets to storms; and the magnetic force of the earth would have to do with the mechanical adjustments and variations of the atmosphere, sometimes causing currents which without it might not exist, and at other times opposing those which might else arise, according as the great differential relations by which it would act (2757.) should combine with or oppose the other natural causes of motion in the air. Such movements would react upon the magnetic forces, so that these would readjust themselves, and so there would be magnetic storms, both material and potential, in the atmosphere, as there are supposed to be of the latter kind in the earth.

2963. In bringing this communication to a close, I have to express my obligations to two kind and able friends, Colonel SABINE and Professor CHRISTIE, for the interest they have taken in the subject, and on the part of the former for the extreme facilities afforded me in the use of observations and the data derived from them; but in doing so I must be careful not to convey any idea that they are at all responsible for the peculiar views I have ventured to put forth. I may well acknowledge that much

* Edin. Phil. Trans., 1836, vol. xiv. p. 25.

which I have written has been upon very insufficient consideration; but hoping that there might be some foundation of truth in the account of the physical cause of the variations which I have ventured to suggest, I have not hesitated to put it forth, trusting that it might be for the advantage of science. The magnetic properties and relations of oxygen are perfectly clear and distinct, and are established by experiment (2774. 2780.); and it is no assumption to carry these properties into the atmosphere, because the atmosphere, as a mere mixture of oxygen and nitrogen, is shown to possess them also (2862.)*. It varies in its magnetic powers, by causes which act upon it under natural circumstances, and make it able to produce some such effects as those I have endeavoured generally to describe.

2964. If it be a cause, in part only, of the observed magnetic variations, it is most important to identify and distinguish such a source of action, even though imperfectly, for the attention is then truly and intelligently directed in respect of the action and the phenomena it can produce. The assigned cause has the advantage of occurring periodically and for the same periods, as a large class of the effects supposed to be produced by it; and if the agreement should appear at first only general, still that agreement will greatly strengthen its claim to our attention. It has the advantage of offering explanations and even suggestions of many other magnetic events besides those which are periodical, and it presents itself at a time when we have no clear knowledge of any other physical cause for the variations, but are constrained vaguely to refer them to imaginary currents of electricity in the air or space above, or in the earth beneath.

2965. The causes, both of the original power and of its secular variations, are unknown to us. But if, accepting the earth as a magnet, we should be able to distinguish largely between internal and external action, and so separate a great class of phenomena from the rest, we should be enabled to define more exactly that which we require to know in both directions, should be competent to state distinctly the problems which need solution, and be far better able to appreciate any new hints from nature respecting the *source* of the power and the effects that it presents to us.

2966. The magnetic constitution of oxygen seems to me wonderful. It is in the air what iron is in the earth. The almost entire disappearance of this property also, when it enters into combination, is most impressive, as in the oxynitrogens and oxycarbons, and even with iron, which it reduces into a condition far below either the metal or the oxygen, weight for weight. Again, its striking contrast with the nitrogen, which dilutes it, impresses the mind, and by the difference recalls that which also exists between them in relation to static electricity (1464.) and the lightning flash. Chlorine, bromine, cyanogen and its congeners, chemically speaking, have no magnetic relation to oxygen. In nature it stands in this respect, as in all its chemical actions, alone.

2967. There is much to do with oxygen relative to atmospheric magnetism. Its

* Philosophical Magazine, 1847, vol. xxxi. pp. 409, 406.

proportion of paramagnetic force at different temperatures and different degrees of rarefaction, will require to be accurately ascertained, and this I hope to effect by a torsion balance, in course of construction (2783.). Indeed, I hope that this great subject may be largely touched and tried by experiment as well as by observation, and therefore gladly make it part of these experimental researches.

2968. One can scarcely think upon the subject of atmospheric magnetism without having another great question suggested to the mind (2442.), What is the final purpose in nature of this magnetic condition of the atmosphere, and its liability to annual and diurnal variations, and its entire loss by entering into combination either in combustion or respiration? No doubt there is one or more, for nothing is superfluous there. We find no remainders or surplusage of action in physical forces. The smallest provision is as essential as the greatest. None are deficient, none can be spared.

Royal Institution,
September 14, 1850.

APPENDIX.

Received November 12, 1850.

The following Tables of data obtained at Toronto, St. Petersburgh, Washington, Lake Athabasca and Fort Simpson, supplied to me by the kindness of Colonel SABINE, have not yet been published. The data for Hobarton and Greenwich are in the volumes of observations for those stations.

Toronto.—Longitude 77° 5′ West. Latitude 43° 40′ North. Approximate declination 1° 25′ West. Mean inclination 75° 15′ North.

Diurnal variation of the Declination in the several months, from July 1842 to June 1848 inclusive.

Increasing numbers denote a movement of the south or upper end of the magnet towards the West.

Toronto mean time.	0h. Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h. Midn.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	0·87	0·00	0·00	0·53	1·44	2·28	2·89	3·47	4·43	4·53	4·39	4·06	3·66	3·42	3·63	3·87	4·46	5·84	3·88	4·44	5·48	5·80	4·79	3·03	3·30
February	0·78	0·00	0·06	0·94	1·58	1·91	2·73	3·13	4·02	4·44	4·69	4·45	4·31	3·81	3·54	4·07	3·97	4·86	4·95	5·20	5·97	5·70	4·64	2·53	3·43
March	1·44	0·01	0·00	0·59	1·74	2·90	3·82	4·77	5·63	6·60	6·47	6·86	6·04	6·42	6·55	6·34	6·69	6·59	7·10	8·30	9·38	9·40	7·15	4·22	5·21
April	1·25	0·00	0·16	1·02	2·76	4·12	5·14	6·31	7·05	7·14	7·60	7·66	7·39	7·32	7·65	7·82	8·08	8·33	9·46	10·09	10·20	9·10	6·87	3·74	6·09
May	1·16	0·00	0·29	1·56	3·24	5·11	6·08	6·27	6·18	6·75	7·36	7·49	7·40	7·26	6·72	7·10	7·80	9·70	11·02	12·16	12·03	10·28	6·90	3·52	6·39
June	1·37	0·00	0·02	0·94	2·53	4·35	5·45	6·11	6·10	6·66	6·66	6·87	6·77	6·50	6·37	6·36	7·29	9·03	11·34	12·34	12·09	10·54	7·67	4·04	6·12
July	1·53	0·00	0·00	0·84	2·18	3·98	5·20	5·77	6·31	6·34	7·31	7·38	7·67	7·06	6·42	6·37	6·86	8·53	10·54	12·01	12·22	10·69	7·65	4·27	6·13
August	1·11	0·00	0·73	2·61	4·52	6·12	7·60	7·52	8·05	8·97	8·51	8·40	8·14	7·69	7·65	7·83	8·24	9·50	12·09	13·89	13·79	11·51	7·31	2·73	7·31
September	0·93	0·00	0·76	2·92	4·62	6·04	6·78	6·83	7·62	7·84	7·83	7·08	7·50	7·66	7·53	7·77	8·45	8·38	9·79	11·16	10·24	8·60	5·34	2·25	6·37
October	0·48	0·00	0·31	1·38	2·38	3·06	3·84	4·33	4·92	5·76	5·68	5·48	5·00	5·21	4·89	5·16	5·82	5·74	5·50	6·39	7·32	7·02	5·17	2·63	3·89
November	0·75	0·00	0·34	1·37	2·21	2·91	3·96	4·89	5·16	5·70	5·54	5·26	4·51	3·79	3·80	4·51	4·44	4·99	4·95	5·70	6·31	6·08	4·57	2·35	3·92
December	1·20	0·18	0·00	0·61	1·67	2·56	3·30	3·89	4·39	4·62	4·95	4·48	4·09	3·49	3·04	3·56	3·92	4·02	3·81	4·18	4·50	5·22	4·67	2·83	3·30

Toronto.—Mean Diurnal variation of the Inclination in the several months, from July 1842 to June 1848.

Increasing numbers denote increasing inclination.

Toronto mean time.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	1·02	0·77	0·53	0·22	0·00	0·09	0·16	0·21	0·25	0·33	0·34	0·38	0·47	0·54	0·58	0·45	0·33	0·28	0·22	0·21	0·36	0·54	1·04	1·06	0·43
February	0·86	0·61	0·36	0·12	0·01	0·00	0·09	0·12	0·19	0·26	0·27	0·31	0·37	0·45	0·49	0·44	0·41	0·30	0·27	0·44	0·69	0·70	0·79	0·86	0·39
March	1·02	0·77	0·47	0·14	0·00	0·00	0·12	0·22	0·24	0·35	0·40	0·44	0·43	0·53	0·50	0·50	0·46	0·46	0·47	0·62	0·81	0·95	1·00	1·05	0·50
April	0·99	0·77	0·54	0·17	0·05	0·00	0·14	0·35	0·49	0·53	0·49	0·61	0·56	0·59	0·64	0·61	0·60	0·66	0·74	0·80	0·90	1·03	1·16	1·16	0·61
May	0·83	0·52	0·22	0·06	0·00	0·11	0·27	0·33	0·47	0·62	0·64	0·66	0·76	0·86	0·87	0·89	0·92	1·04	1·00	1·01	1·11	1·29	1·30	1·12	0·70
June	0·89	0·60	0·26	0·05	0·00	0·00	0·16	0·34	0·53	0·68	0·73	0·83	0·84	0·90	0·91	0·98	1·03	1·05	1·08	1·12	1·17	1·27	1·37	1·19	0·75
July	0·67	0·55	0·17	0·07	0·00	0·06	0·17	0·24	0·39	0·40	0·51	0·56	0·62	0·56	0·66	0·78	0·83	0·87	0·81	0·80	0·88	1·03	1·14	0·93	0·57
August	0·85	0·51	0·21	0·00	0·02	0·04	0·25	0·40	0·42	0·44	0·48	0·55	0·53	0·64	0·65	0·73	0·74	0·84	0·89	1·00	1·09	1·25	1·26	1·13	0·62
September	1·35	0·82	0·35	0·10	0·00	0·10	0·29	0·49	0·53	0·55	0·57	0·63	0·68	0·70	0·70	0·75	0·57	0·65	0·68	0·95	1·28	1·64	1·85	1·71	0·75
October	0·93	0·67	0·39	0·14	0·00	0·06	0·21	0·30	0·37	0·39	0·40	0·49	0·62	0·45	0·40	0·33	0·22	0·22	0·32	0·55	0·85	1·04	1·15	1·11	0·48
November	0·94	0·75	0·45	0·22	0·11	0·18	0·12	0·18	0·20	0·20	0·23	0·33	0·33	0·31	0·21	0·22	0·12	0·07	0·00	0·08	0·42	0·14	0·89	1·00	0·32
December	0·91	0·88	0·51	0·27	0·05	0·01	0·02	0·16	0·21	0·27	0·33	0·30	0·38	0·34	0·28	0·22	0·14	0·08	0·09	0·00	0·17	0·34	0·66	0·81	0·31
Hourly means	0·94	0·69	0·37	0·13	0·02	0·05	0·17	0·28	0·36	0·42	0·45	0·51	0·55	0·57	0·57	0·58	0·53	0·54	0·55	0·63	0·81	0·93	1·13	1·10	0·54

Toronto.—Mean Diurnal variation of the Total Force in the several months, from July 1842 to June 1848.

Increasing numbers denote increasing Force. Mean Total Force at Toronto 13·9.

The figures express the changes in parts of the whole Force.

Toronto mean time.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	005	011	017	023	022	024	023	023	023	020	019	015	010	009	004	003	004	005	008	009	010	003	000	000	012
February	006	012	019	022	024	026	026	027	025	023	019	017	009	005	003	004	003	006	009	010	016	004	000	001	013
March	004	011	019	026	029	031	031	031	028	025	020	014	005	002	002	002	003	003	010	013	013	007	002	000	014
April	012	020	031	039	045	045	044	039	034	027	020	012	008	007	003	000	009	011	013	012	012	009	006	006	019
May	004	013	015	031	038	042	038	035	029	025	017	011	004	002	002	003	008	010	015	013	009	003	000	000	015
June	003	008	017	025	029	031	030	028	022	018	014	011	006	002	002	001	006	011	014	014	010	005	002	000	013
July	015	019	030	038	044	047	043	039	031	026	021	015	007	004	000	002	005	011	016	017	015	014	010	002	020
August	027	034	044	049	057	057	051	046	041	032	023	010	006	001	003	000	006	018	026	026	024	019	019	021	026
September	029	043	053	060	066	056	052	050	044	038	034	029	019	007	000	001	004	009	018	022	028	015	016	021	030
October	013	021	027	032	032	033	033	034	031	026	023	018	007	003	005	002	000	005	011	014	018	011	006	006	017
November	007	014	022	026	028	025	025	028	024	018	015	011	007	004	001	003	000	003	007	009	008	002	001	003	011
December	004	010	019	020	023	021	021	021	019	018	017	012	010	008	006	007	003	003	007	006	006	006	001	000	011
Hourly means	011	018	026	032	036	037	035	033	029	025	020	015	008	005	003	002	004	008	013	014	014	008	005	006	017

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Toronto.—Mean Temperature of the Air in the several months, from July 1842 to June 1848, in degrees of FAHRENHEIT's scale.

Toronto mean time.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	27°8	28°2	28°6	28°5	28°0	27°1	26°3	25°8	25°5	25°3	26°3	24°6	23°6	23°5	23°4	21°6	23°2	23°0	23°7	23°6	23°9	24°8	26°0	27°1	25°48
February	27·4	28·2	28·5	28·5	28·0	26·9	25·6	24·6	23·8	23·2	22·7	22·2	22·0	21·7	21·3	20·9	21·5	20·2	20·0	19·9	20·9	22·9	24·9	26·3	23·80
March	33·8	34·4	35·0	34·9	34·3	33·6	31·9	30·5	29·5	28·6	28·0	27·3	27·3	26·8	26·3	26·2	25·8	25·5	25·0	25·9	27·8	29·9	31·6	32·8	29·71
April	47·6	48·5	49·0	49·0	48·6	47·9	46·1	43·5	41·8	40·7	39·8	39·3	39·1	38·6	37·9	37·3	37·0	36·6	36·8	39·2	41·5	43·6	45·2	46·6	42·55
May	59·0	59·9	60·2	60·3	60·3	59·9	58·1	55·2	52·6	50·7	49·7	48·8	48·0	46·9	46·3	45·6	45·1	45·2	47·6	50·6	53·0	55·2	56·8	58·0	53·04
June	66·7	67·5	67·9	68·3	68·5	68·1	66·6	63·9	60·6	58·4	57·0	56·1	55·7	54·8	54·1	53·3	52·7	52·9	55·6	58·5	60·8	62·7	64·4	65·6	60·86
July	72·9	73·7	74·5	74·8	74·7	74·3	72·7	69·2	65·1	62·9	61·8	60·7	59·8	58·9	58·3	57·6	56·9	56·9	59·8	63·4	66·0	68·2	70·1	71·5	66·02
August	73·0	73·9	74·5	74·8	74·6	74·1	72·5	68·4	65·3	63·6	62·4	61·6	60·7	60·0	59·4	58·7	58·3	58·1	59·6	63·2	66·3	68·7	70·6	72·1	66·43
September	63·9	64·5	64·9	64·9	64·7	63·7	61·1	58·3	57·1	56·0	54·9	54·2	53·8	53·3	52·7	52·2	51·6	51·1	51·7	54·2	57·0	59·5	61·5	62·9	57·90
October	49·7	50·2	50·5	50·3	49·6	47·8	45·8	44·7	43·9	43·1	42·3	41·6	41·0	40·4	40·1	39·9	39·5	39·4	39·6	40·4	42·8	45·6	47·5	48·9	44·35
November	39·5	40·0	40·1	39·9	39·0	37·7	36·9	36·3	35·9	35·7	35·3	34·9	34·3	34·0	33·7	33·4	33·2	33·3	33·6	33·6	34·6	36·2	37·7	38·8	36·15
December	29·9	30·4	30·7	30·5	29·8	28·9	28·2	27·9	27·5	27·3	27·0	26·9	26·6	26·0	25·7	25·5	25·5	25·5	25·1	25·0	25·4	26·6	27·9	29·1	27·44
Hourly means	49·27	49·97	50·37	50·39	50·01	49·17	47·65	45·69	44·05	42·96	42·27	41·52	41·16	40·41	39·93	39·35	39·11	38·97	39·84	41·46	43·33	45·32	47·02	48·31	44·48

St. Petersburgh.—Longitude 38° 18′ East. Latitude 59° 57′ North. Mean declination 6° 10′ West.

Mean Diurnal variation of the Declination in the several months, from 1841 to 1845 inclusive.

Increasing numbers denote a movement of the south or upper end of the magnet towards the West.

Mean time ...	Noon. h m 0 21½	h m 1 21½	h m 2 21½	h m 3 21½	h m 4 21½	h m 5 21½	h m 6 21½	h m 7 21½	h m 8 21½	h m 9 21½	h m 10 21½	h m 11 21½	Midn. h m 12 21½	h m 13 21½	h m 14 21½	h m 15 21½	h m 16 21½	h m 17 21½	h m 18 21½	h m 19 21½	h m 20 21½	h m 21 21½	h m 22 21½	h m 23 21½	Means.
January	0·27	0·00	0·36	1·24	1·59	1·99	2·39	2·28	4·03	4·65	4·56	4·65	4·42	3·79	3·77	3·10	2·57	2·22	2·35	2·17	2·08	1·86	1·42	1·02	2·49
February	0·84	0·00	0·09	0·57	1·55	2·84	3·54	3·63	4·03	5·18	5·67	5·49	5·27	4·52	4·34	4·65	4·34	3·90	4·03	3·77	3·50	3·23	2·61	1·46	3·29
March	0·89	0·00	0·04	1·15	2·88	4·16	5·36	6·29	6·73	6·78	7·40	7·84	6·69	6·51	5·76	6·11	6·38	6·16	6·65	6·56	6·73	6·38	4·96	2·79	5·05
April	1·59	0·00	0·36	2·17	4·03	5·54	7·04	7·93	8·33	8·02	9·30	9·17	8·68	8·46	8·73	8·59	9·17	9·30	9·48	10·01	10·68	9·75	7·58	4·61	7·01
May	1·02	0·00	0·62	2·13	3·68	5·49	6·96	7·44	7·18	6·82	7·44	8·24	8·55	8·73	8·82	9 66	10·23	10·72	11·12	11·39	11·12	9·92	7·49	3·54	7·01
June	1·77	0·00	0·00	1·37	2·92	4·52	5·76	6·25	6·25	6·56	7·13	7·13	7·49	8·28	8·68	9·70	10·23	10·94	11·30	11·39	11·52	10·10	7·35	4·12	6·70
July.....	1·46	0·04	0·00	1·11	2·39	3·94	4·96	5·27	5·98	5·98	6·78	7·49	7·66	7·71	8·42	8·55	9·30	9·52	9·83	9·75	9·04	8·46	6·96	3·90	6·02
August	0·27	0·00	0·40	2·44	4·16	5·94	7·04	6·73	7·49	7·27	7·35	7·27	8·02	8·11	8·06	8·55	9·30	9·88	10·19	10·19	9·44	8·42	5·67	3·15	6·47
September ...	0·57	0·00	0·84	2·57	4·30	6·33	6·79	7·49	7·97	8·06	8·33	7·49	7·04	7·31	7·49	6·78	7·04	6·91	7·27	7·31	7·13	6·25	4·12	1·95	5·73
October	0·31	0·00	0·48	1·77	3·59	4·08	4·87	5·76	6·02	6·56	6·91	6·20	5·71	5·18	4·78	4·39	4·16	3·99	4·21	4·83	5·09	4·65	3·32	1·59	4·10
November ...	0·09	0·00	0·36	1·55	1·90	2·71	2·79	3·15	3·81	4·39	4·47	4·34	3·68	3·06	2·75	2·35	2·22	1·82	1·82	1·90	1·77	1·77	0·93	0·57	2·26
December ...	0·53	0·00	0·36	1·24	1·82	2·39	2·79	2·97	4·03	4·56	4·56	4·52	3·68	3·10	2·88	2·53	2·04	1·82	1·77	1·77	1·82	1·68	1·28	0·93	2·29
Hourly means	0·80	0·00	0·33	1·61	2·90	4·16	5·02	5·52	5·99	6·24	6·66	6·65	6·41	6·22	6·20	6·25	6·42	6·43	6·67	6·75	6·66	6·04	4·47	2·47	4·87

St. Petersburgh.—Mean Temperature of the Air in the several months, from 1841 to 1845 inclusive. FAHRENHEIT's scale.

Mean time ...	Noon. h m 0 21½	h m 1 21½	h m 2 21½	h m 3 21½	h m 4 21½	h m 5 21½	h m 6 21½	h m 7 21½	h m 8 21½	h m 9 21½	h m 10 21½	h m 11 21½	Midn. h m 12 21½	h m 13 21½	h m 14 21½	h m 15 21½	h m 16 21½	h m 17 21½	h m 18 21½	h m 19 21½	h m 20 21½	h m 21 21½	h m 22 21½	h m 23 21½	h m
January	20°28	20°71	20°67	20°41	18°82	18°89	18°73	18°71	18°74	18°76	18°67	18°49	18°38	18°33	18°29	18°19	18°04	18°90	18°79	18°79	18°74	18°81	18°24	18°98	
February	18·34	18·58	18·70	18·65	18·27	17·35	16·88	16·52	16·32	16·09	15·95	15·67	15·55	15·48	15·39	15·19	14·97	14·88	14·76	14·65	15·19	15·66	16·61	17·35	
March	25·61	26·30	26·97	27·01	27·01	26·13	24·74	23·88	23·20	22·44	21·94	21·31	20·70	20·07	19·62	19·26	18·84	18·54	18·34	18·74	19·87	21·38	22·95	24·53	
April	37·85	38·07	38·58	38·81	39·53	38·63	36·54	34·62	33·35	32·38	31·42	30·72	30·07	29·55	29·08	28·61	28·36	28·42	29·21	30·63	32·16	33·75	35·39	36·79	
May	53·46	53·80	54·31	54·72	55·10	54·29	52·23	49·84	47·91	46·19	45·38	43·90	43·16	42·37	41·83	41·47	41·56	42·73	44·19	46·06	47·88	49·57	51·17	52·65	
June	63·03	63·48	63·83	64·36	64·97	64·07	61·90	59·97	58·19	56·48	55·04	54·07	53·26	52·58	52·00	51·50	52·27	53·33	54·95	56·57	58·21	59·72	59·02	62·15	
July.....	66·44	66·93	67·21	67·46	67·93	67·26	65·28	63·61	62·01	60·57	59·56	58·86	58·05	57·33	56·86	56·48	56·68	57·53	58·86	60·59	62·06	63·43	64·76	65·90	
August	67·10	68·00	68·56	68·69	69·23	68·56	65·73	63·70	62·26	60·89	60·08	59·22	58·14	57·60	57·20	56·57	56·14	56·73	57·65	59·45	61·29	63·12	64·71	66·06	
September	54·50	55·66	55·91	55·78	55·83	54·56	52·62	51·16	50·15	49·43	48·89	48·31	47·75	47·25	46·85	46·44	46·26	46·06	46·17	47·21	48·76	50·56	52·20	53·37	
October	41·92	44·90	42·76	41·96	41·78	40·92	40·30	39·89	39·56	39·31	38·86	38·52	38·32	38·14	38·00	37·85	37·73	37·67	37·53	37·71	38·28	39·11	40·12	41·04	
November ...	29·73	30·22	30·88	29·75	29·26	28·96	28·83	28·67	28·58	28·41	28·52	28·49	28·47	28·45	28·42	28·27	28·13	28·04	28·00	27·95	28·07	28·42	28·83	29·37	
December ...	26·04	26·45	26·40	26·27	26·13	25·91	25·70	26·02	25·52	25·48	25·48	25·32	25·21	25·12	24·96	24·85	24·85	24·92	25·03	25·03	25·14	25·25	25·39	25·79	

Washington, U.S—Longitude 77° 2′ West. Latitude 38° 54′ North. Mean declination 1° 25′ West. Mean dip 71° 20′ North.

Mean Diurnal variation of the Declination in minutes, and temperature in FAHRENHEIT's scale, of the months of the years 1840, 1841, 1842, which are specified.

Increasing numbers denote a movement of the south or upper end towards the East.

Mean time	Noon. h m 0 12	h m 2 12	h m 4 12	h m 6 12	h m 8 12	h m 10 12	h m 12 12	h m 14 12	h m 16 12	h m 18 12	h m 20 12	h m 22 12	Mean.
January 1841–42	4·10	5·20	3·96	2·52	0·87	0·68	1·01	1·62	1·66	1·71	0·91	0·29	2·04
February 1841–42	3·55	5·28	4·22	2·89	1·59	0·94	0·84	1·26	0·81	0·82	0·60	0·35	1·76
March 1841–42 ...	6·34	7·51	6·26	4·25	2·88	2·31	2·50	3·00	1·71	1·13	0·00	1·76	3·30
April 1841–42 ...	6·56	8·33	6·42	4·41	3·22	1·97	2·24	1·35	0·73	0·46	0·00	2·18	3·15
May 1841–42.....	7·72	8·57	6·36	4·45	3·82	3·47	3·25	3·05	2·63	0·33	0·00	4·25	3·99
June 1841–42.....	8·55	9·47	8·00	5·33	4·91	4·24	4·05	4·32	3·44	0·63	0·00	4·53	4·79
July 1840–41.....	8·42	9·87	8·07	5·75	4·57	3·52	3·60	3·40	2·99	0·98	0·00	3·62	4·56
August 1840–41...	10·94	10·81	7·95	6·00	4·03	3·55	4·48	4·64	4·04	1·35	0·00	5·89	5·30
Sept. 1840–41.....	8·76	8·44	5·43	4·45	2·62	3·31	2·83	2·86	2·44	0·87	0·00	4·22	3·85
October 1840–41	5·65	5·83	4·35	2·47	1·41	0·58	1·41	1·80	1·51	1·35	0·00	1·75	2·34
Nov. 1840–41.....	4·69	4·79	3·33	1·60	0·51	0·74	1·14	1·41	0·82	0·71	0·00	1·83	1·79
Dec. 1840–41.....	3·93	4·90	3·39	1·92	0·10	0·36	0·62	1·53	0·93	2·00	1·02	0·87	1·79

Temperature.

Mean time	Noon. h m 0 12	h m 2 12	h m 4 12	h m 6 12	h m 8 12	h m 10 12	h m 12 12	h m 14 12	h m 16 12	h m 18 12	h m 20 12	h m 22 12
January 1841–42	38·28	40·83	40·18	36·68	35·47	34·24	33·37	32·10	31·71	36·53	31·63	36·96
February 1841–42	40·03	42·51	42·28	38·22	35·38	33·86	32·58	31·22	30·51	30·18	31·44	36·72
March 1841–42 ...	51·39	53·61	53·28	49·96	46·20	44·37	42·48	41·26	40·06	39·87	42·28	48·06
April 1841–42 ...	57·68	59·81	60·20	57·21	52·18	49·12	47·91	46·91	46·12	46·49	49·93	54·02
May 1841–42.....	66·37	68·48	68·69	65·93	59·83	56·70	55·19	53·34	52·42	55·50	59·72	63·23
June 1841–42.....	79·32	81·85	82·75	76·89	72·29	68·70	66·83	66·04	65·07	68·26	73·63	77·37
July 1841	81·13	81·53	84·60	81·33	74·93	71·56	68·78	68·09	66·78	70·64	75·19	78·38
August 1840–41...	78·70	80·73	80·09	75·93	71·48	68·00	66·82	65·12	64·17	65·69	65·73	76·09
September 1841...	74·66	76·50	76·30	72·30	68·59	64·90	62·70	61·90	61·00	61·29	65·73	71·02
October 1841.....	55·30	57·00	56·20	52·94	48·40	46·60	44·90	43·70	42·30	41·70	45·00	51·61
November 1841 ...	48·00	49·20	48·50	47·30	44·20	43·20	41·80	40·70	39·40	38·80	39·50	44·10
December 1841 ...	39·20	41·30	40·60	37·95	36·26	34·70	33·50	33·16	32·20	31·60	31·69	36·00

Lake Athabasca.—Longitude 111° 18′ West. Latitude 58° 41′ North. Mean declination 28° East.

Diurnal variation of the Declination in the months of October, November and December 1843, and January and February 1844.

Increasing readings denote a movement of the south or upper end of the magnet towards the West.

Mean time }	h m 12 55	h m 13 55	h m 14 55	h m 15 55	h m 16 55	h m 17 55	h m 18 55	h m 19 55	h m 20 55	h m 21 55	h m 22 55	5 minutes to noon. h m 23 55	h m 0 55	h m 1 55	h m 2 55	h m 3 55	h m 4 55	h m 5 55	h m 6 55	h m 7 55	h m 8 55	h m 9 55	h m 10 55	5 minutes to midnight. h m 11 55	Mean time.
1843. Oct....	1·13	1·49	6·23	18·95	21·32	8·55	15·35	9·90	10·72	7·03	2·29	2·70	0·00	0·29	0·02	0·98	0·49	2·88	1·88	3·75	3·47	3·30	8·42	0·49	13 days obs. in Oct. 1843.
Nov....	3·73	5·17	6·74	9·07	10·35	10·80	9·40	8·80	7·63	6·54	1·10	0·00	1·06	1·57	1·93	2·73	2·94	3·34	4·52	4·97	5·43	7·08	3·04	3·63	25 days obs. in Nov. 1843.
Dec....	3·04	6·16	5·57	5·65	9·23	7·61	9·78	6·73	6·58	5·33	1·94	0·55	0·03	0·00	0·83	2·37	2·63	3·81	4·18	3·57	4·35	7·19	4·05	6·05	25 days obs. in Dec. 1843.
1844. Jan....	5·69	8·48	6·97	12·57	16·29	10·05	9·97	10·02	9·96	7·95	4·99	2·10	0·39	0·00	2·75	1·67	2·47	3·63	4·72	5·15	5·44	3·97	6·71	2·18	25 days obs. in Jan. 1844.
Feb....	4·27	4·93	8·46	10·55	14·80	14·87	14·06	12·10	12·76	8·64	2·82	2·93	1·55	0·00	1·48	3·24	3·76	4·52	4·96	5·48	5·58	4·99	6·98	5·40	25 days obs. in Feb. 1844.

Fort Simpson.—Longitude 121° 30′ West. Latitude 61° 52′ North.

Diurnal variation of the Declination in the months of April and May 1844.

Increasing numbers denote a movement of the south or upper end of the magnet towards the West.

Mean time. }	15 minutes past midnight. h m 12 15	h m 13 15	h m 14 15	h m 15 15	h m 16 15	h m 17 15	h m 18 15	h m 19 15	h m 20 15	h m 21 15	h m 22 15	h m 23 15	15 minutes past noon. h m 0 15	h m 1 15	h m 2 15	h m 3 15	h m 4 15	h m 5 15	h m 6 15	h m 7 15	h m 8 15	h m 9 15	h m 10 15	h m 11 15	Mean time.
1844. April	5·82	6·03	17·45	25·16	22·90	36·80	36·26	37·60	30·14	25·27	18·77	6·27	5·72	2·16	6·00	1·37	1·23	0·43	0·30	1·04	4·62	1·26	2·86	5·55	20 days obs. in Apr. 1844.
May	1·56	7·77	11·71	15·63	17·19	23·73	28·22	32·69	29·80	20·29	15·51	9·49	4·74	3·75	0·70	0·75	0·80	0·00	0·19	1·90	6·72	3·51	2·29	1·67	18 days obs. in May 1844.

IV. *Experimental Researches in Electricity.—Twenty-seventh Series.* By MICHAEL FARADAY, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.*

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§ 33. *On Atmospheric Magnetism—continued.*

¶ ii. *Experimental inquiry into the laws of atmospheric magnetic action, and their application to particular cases.*

2969. BELIEVING that experiment may do much for the development of the general principles of atmospheric magnetism, and produce rapidly a body of facts on which philosophers may proceed hereafter to raise a superstructure, I endeavoured to find some means of representing practically the action of the atmosphere, when heated by the sun, upon the terrestrial magnetic curves. The object was to obtain some central arrangement of force which should deflect these curves or lines as they are deflected in a diamagnetic conductor or globe of hot air (2877.), and then apply the results obtained by such an arrangement as a partial test to the various cases supplied by the magnetic observatories scattered over the earth. At first I endeavoured, for the sake of convenience, to attain this desired end by means of a horseshoe magnet, employing the lines which passed from pole to pole to disturb and rearrange the earth's force; but the comparative weakness of the terrestrial force near the magnet, and the great prominence of the poles of the latter, gave rise to many inconveniences, which soon caused me to reject that method and have recourse to a ring-helix and voltaic apparatus. Considering the new use to which this helix is to be applied, the interest of the results, and the instruction that may be drawn from them, I shall be excused for being somewhat elementary in the description of its character and action.

2970. The helix consisted of about 12 feet of covered copper wire formed into a ring having about twenty-five convolutions, and being 1½ inch in external diameter. The continuations of the wire were twisted together so as to neutralize any magnetic effect which they could produce, and were long enough to reach to a voltaic arrangement, and yet allow free motion of the helix. The requisite amount of magnetic power in the helix may be judged of by the following considerations:—Suppose a declination needle freely suspended; and then the *helix* placed at a distance in the prolongation of the needle with its axis in a line with the latter, and with that side to-

wards the needle which will at small distances cause repulsion. The needle will point, in the magnetic meridian, with a certain amount of force; but as the helix is brought near it will point with less force, and within a certain distance will no longer point in the magnetic meridian, but either on one or the other side of it. There is a given distance within which the needle, when in the magnetic meridian, is in a position of unstable equilibrium, but beyond which it has a position of stable equilibrium, the distance varying with the strength of the exciting electric current. The power of the helix should be such, that when end on to the needle the latter has a position of stable equilibrium in the meridian. One pair of plates is quite sufficient to make the helix as magnetic as is needful for distances varying from 4 to 24 inches. When a needle is properly arranged with either a magnet or a helix to the north or south of it as above described, if the magnet or helix be moved west the near end of the needle will move east, and contrariwise.

2971. As is well known, such a helix has a system of magnetic lines, which, passing through its axis, then open out and turning round on the outside re-enters again at the axis, the circles of magnetic force being everywhere perpendicular to the electric current traversing the convolutions of the helix; and now I had, at a moment's notice, a source of lines of magnetic power exactly of the kind required to produce, in association with those of the earth, a disposition of the forces coinciding either with those of paramagnetic or diamagnetic polarization (2865. 2877.).

2972. For let fig. 17 represent a section parallel to the axis of the ring-helix, then the two circles may represent the disposition of the magnetic force in that section, and the arrow-heads may serve to indicate that magnetic direction which belongs to lines of force issuing out of the north end of a magnet. If such a system be suddenly produced in the midst of the earth's lines, it acts upon them according to the position of the helix in relation to the direction of the earth's power. Choosing the two positions in which the axis of the helix is parallel to the natural direction of the power, as shown by a free needle, at the place of observation, then two contrary effects are produced, which, as regards the lines exterior to the helix system, correspond to the polarity of paramagnetic and diamagnetic conductors. If, for instance, the helix is so placed that the polarity of its magnetic lines, exterior to and in the plane of the ring, accords with that of the earth's force, as in fig. 18, then the earth's lines are deflected as represented, and a magnetic needle placed at *a*, which had taken up its position by the earth's influence, will not tend to alter its position as the helix approaches it, though it will be acted on with more power. In other parts of the line, *b a c*, it will alter its position, standing as a tangent to the curvature, and therefore will be deflected sometimes one way and sometimes another, as it is carried along the line (or through the neighbouring lines), in place of remaining parallel to itself, as it would do if the electro-magnetic helix were away.

Fig. 17.

Fig. 18.

2973. On the other hand, if the helix were turned round into the second position

(2972.), then the effect upon the direction of the neighbouring lines of force would be as in fig. 19. Needles placed at *d* and *e* would again be deflected from the natural position given to them by the earth, but they would be deflected in a contrary direction to that which would be taken if they were in corresponding situations under the former arrangement. This figure and state of things represents the paramagnetic disposition of the forces, as the former did the diamagnetic condition.

Fig. 19.

2974. It is not pretended that the whole of these arrangements of forces are like those of the cases of paramagnetic and diamagnetic conductors. Independent systems are here introduced into the midst of the earth's magnetic power, and the central part of each arrangement must therefore be excepted; there are also attractions inwards and repulsions outwards, when the needle is at *a* and *f*, which do not take place in the cases of mere magnetic conduction. But external to these helix systems, the arrangement imposed upon the lines of force from the earth is in accordance with that produced by diamagnetic and paramagnetic conductors, and at distances from 2 inches to 2 or 3 feet; the lines of force thus altered, and those contorted by the sun and atmosphere in the great field of nature, are comparable in their direction, and may be considered as representing each other.

2975. In order to obtain a simple result of the action of such a centre of force on the magnetic lines of the earth, I adjusted a rod in the direction of the dipping-needle, and also a plane at the foot of it parallel to the magnetic equator at London. Then suspending a small magnet, half an inch long, from cocoon-silk, so that when hanging it should be parallel to the magnetic equator, it was adjusted so as to be near to the plane at the foot of the rod representing dip. The ring-helix (2970.) was then associated with the voltaic pair, so that contact could be completed at any moment, and being always retained parallel to itself and to the plane of the magnetic equator, could be brought into the vicinity of the needle on all sides, above or below, and its action upon it observed. As the object was to represent the sun's action, the current was so sent through the helix that its upper face would repel the north end of a magnetic needle; for then a magnet, outside of and in the plane of the ring, would not tend to have its position changed, and the disposition of the forces of the earth under the influence of the helix was as in fig. 18, or like that of a diamagnetic conductor.

2976. In making observations of this kind, and especially if the ring-helix is purposely retained at a considerable distance from the needle, it is better not to connect the helix permanently with the battery and then carry it towards and by the needle, but rather to choose the place where the helix action is to be observed, and when the helix is there to make contact with the battery; the motion and direction of the needle is then easily observed; or if it still, through reason of distance, be feeble, making and breaking contact a few times isochronously with the vibrations of the needle soon raises the effect to any degree required.

2977. There are certain positions in respect of the needle as a centre which must be clearly comprehended. The magnetic axis is a line through the centre of the free regular needle parallel to the direction of the earth's lines of force, whatever that may be, at the place where the experiments may be made. The magnetic equator plane is a plane passing through the centre of the needle perpendicular to the magnetic axis. The plane of the magnetic meridian is that plane which coincides with the magnetic axis, and also with the direction in which the declination needle points. This position always occurs with the magnets that are employed for observation, being a consequence of the method in which they are supported; it would not be taken by a needle placed at right angles on its mechanical axis, the latter being in the magnetic axis.

2978. When the ring-helix, situated as before explained (2975.), was anywhere in the plane of the *magnetic meridian*, it exerted no action on the declination needle tending to change its position. When the helix was anywhere in the plane of the magnetic equator, it exerted no action on the needle to make it change its direction. These are the only places in which the helix does not affect the position of the needle.

2979. These two planes of no variation divide the space around the magnet into four quadrants, and the helix being in any one of these, affects the needle, altering its declination. The deflection of the line of force for two neighbouring quadrants is in the contrary direction, so that as the helix passes from the neutral line into one or the other quadrant, the declination of the needle changes.

2980. If the helix be above or below the magnetic equator and be carried round the magnetic axis travelling along a line of latitude, then the needle makes *one* large oscillation to the right, and another to the left during the circuit. Supposing that the experiment commences with the helix above the equator, and in the plane of the magnetic meridian north of the needle, if it then proceeds by west to south and on by east to its original position the north end of the needle will first go westward; will then stop and return eastward, passing the mean position, and will finally return westward and settle in its first or original direction. All the time the helix is to magnetic east of the needle it will cause the same deflection, and also as long as it is in the west; the deflection will be more or less, but not change in direction as regards the neutral place. The position of the helix north or south of the needle is of no consequence as to the direction of the declination, provided it remain on the same side of the magnetic meridian, though it is to the amount. If the helix be below the magnetic equator the direction of the declination is reversed, but then again it does not change whilst the helix remains east or west of the needle and its plane of mean declination.

2981. If we carry the helix round the needle in a plane perpendicular to the planes of the magnetic equator and meridian, so as to traverse in succession the four quadrants, then the needle makes *two* to and fro vibrations (instead of one) during the

circuit. Thus, beginning with the helix in the neutral position over the needle and going round by west and below, and then upwards on the east side to its first position, the north end of the needle will first pass westward, then eastward, then westward, after that eastward, and finally westward to its original or neutral position.

2982. As the helix is carried from the neutral planes (2978.) into any of the quadrants, the power of affecting the declination of the needle is first developed, and then increases every way, from the edges of the quadrant until it attains its maximum force at the middle. Hence the maximum deflection east or west is when the helix is in the middle of each quadrant. Therefore, when the helix is carried from the middle of one quadrant to the middle of the next, only *one motion* in the needle appears; as for instance, an increasing westerly declination, though the direction of the declination in relation to the mean position has been reversed in that time, and there was a moment when the needle had no extra declination, but was *in* that mean position. So also as the helix moves over one quadrant from one neutral plane to another, though the declination of the needle produced by it has not changed in direction, but has been, for instance, all the time west, still the needle will have exhibited two motions, going first west during the increase of the power, and then east whilst it is diminishing; and hence it is that though there are *four* departures of the needle from and return to the neutral or mean position, whilst the helix circumscribes it in an east and west vertical plane (2981.), there are only *two* complete journeys of the needle.

2983. The amount of the deflection diminishes as the distance of the helix from the needle increases; and the contrary.

2984. Two other needles were slung (2975.) very oblique to the magnetic axis, one with its north end upwards and the other with its north end downwards, and these were submitted to the action of the helix as the former had been (2978.). They were affected exactly in the same manner, showing no difference; *i. e.* a given end always moved the same way for the same change in position of the helix. If the helix was very near, then one pole was a little more influenced than the other in certain positions; but its removal further off took away that difference (which is easily accounted for (2970.)) and produced pure results. The place of the helix above or below the prolongation of the line of the needle made *no difference*, provided it was in the same place as regarded the magnetic equator of the earth's lines of force passing through the needle.

2985. For the purpose of establishing the nature of the action which such a helix, always in the given or diamagnetic position (2975.), would exert upon the *inclination*, a small dipping-needle was submitted to its action and the following results obtained. The needle could move in the plane passing through the magnetic meridian of London.

2986. There was no deflection of the needle when the helix was in the plane of the magnetic equator, or in a plane perpendicular to that containing the mechanical axis

of the needle. In every other position it affected it; so that these two planes divided the sphere of action into four segments, as before.

2987. As the helix passes from one quadrant to another, the direction in which the needle is deflected changes as before (2982.). If the helix is in the upper north segment or the lower south segment, the upper or south end of the needle is deflected towards the south; if the helix be in the upper south or lower north segments, the upper or south end of the needle is deflected towards the north. If the helix be carried round the needle in the direction of the plane of motion, which in this case is that of the magnetic meridian, the end of the needle starting from a mean or unaffected position will move first one way, as for instance, north and then south; north again and south again, and finally north to regain its place of rest: so that there are two extreme deflections of the end in each direction, as before, in the case of the declination magnet (2982.).

2988. In other words, when the helix was anywhere below the magnetic equator, the *lower* or north end of the needle tended to point outwards from it or outside of it, being as it were *repelled* by the axis of the helix, but *drawn* by the outer curved lines of force, fig. 20 (2992.). Or if the helix were above the equator, then the *upper* or south end of the needle went outwards from the helix, moving exactly in the same direction in relation to the helix as the lower pole did before.

2989. The support of the needle was turned round 90°, which therefore removed the plane in which the needle could move 90° from the magnetic meridian. This carried the plane of no action on the needle 90° round, so that it now coincided with the magnetic meridian; and the plane, which, standing east and west, was before neutral, was no longer a plane of indifference, but in fact passed at the middle of the segments through the places of strongest action.

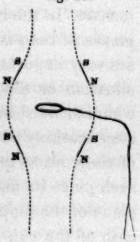
2990. Here, with *inclination*, as before with *declination*, it is not the direction in which the needle stands that determines what action the helix may have upon it; for it may be loaded or otherwise restrained, as all horizontal needles are; but it is the *direction* of the lines of force at the needle which, with the helix, governs all. The helix may be above or below the prolongation of the needle indifferently; for if it still continues on the same side of the line of force, under the influence of which the needle acts, then the end of the needle moves in the same direction, though it may travel towards the helix in one instance and from it in another.

2991. I suspended a needle so that it was free to move in every direction, and now I obtained the simple natural effect of the helix, or a diamagnetic globe (2877.) on a given line of force, and it is well to have it in mind. For, though we are obliged for the sake of practical observation to divide the position into two parts, declination and inclination, yet the results in each case are much better compared and remembered when the simple law of change in the whole line of force is ready in the mind for reference. The equatorial plane and the magnetic axis are now the only parts in which the helix can be without affecting the position of the needle;

the first gives places (for the helix) with a stable position for the needle, and the second such as have either stable or unstable positions, according to the helix distance.

2992. If the helix be out of the plane and axis, then the end of the needle nearest to it leans from it as if repelled. If the helix be carried round in a circle of latitude, the end of the needle moves round before it just like the upper end of the needles at Hobarton and Toronto, in respect of the sun, during the midday hours. Instead of moving the helix round the needle, we may carry the needle into different positions as regards the helix, and then fig. 20 will represent the result. A result exceedingly simple, and in perfect accordance with the diamagnetic disposition of the forces produced by the helix (2972.), as the two dotted lines indicate.

Fig. 20.



2993. As an expression of the facts for use in applying them to the explanation and illustration of natural phenomena, it may be said in respect of *declination*, that the helix being above the needle in a plane having dip, and therefore above its magnetic equator, if on the east of a needle having north dip, it will send the south or upper end west, or if on the east of a needle having south dip (being of course then itself inverted (2972.)), it will cause the north or upper end to pass westward; seeming to repel the end of the free needle or part of the line of force nearest to it. In reference to the *inclination*, it may be said, that the helix being above the needle, tends to send the upper end of the needle or line of force from it. If the helix is north of the magnetic axis, it will tend to send the upper end of the needle south; if it is south, the upper end will go north. As in the case of the declination, it is as if the end of the free needle or line of force nearest to it was repelled. In fact every case is included in this result, that if the helix be diamagnetically adjusted (2975.) for a free needle, whether it is above or below the needle, or on this side or that, the nearest end of the needle will be as if repelled, provided the helix is not in a neutral position.

2994. I repeated all these experiments with the helix reversed, so as to give the effect of a paramagnetic globe of air (2865. 2973.). I need only say, that the effects were precisely the same in nature and order, only in the *reverse* direction. They will be required in the explication of the night and early morning actions, due to the cooling of the atmosphere (3003. 3010.).

2995. In these experiments, that the laws of deflection might appear in their simplicity, the needle was suspended in the air, and the representation of the sun's action carried round it in all directions. But in nature the air is only above the needle, and the earth as a magnet is beneath it. In the natural case also, there is the fixation of the lines in the earth (2919.), which tends, by holding them below the surface, to give them an amount of deflection *at* the surface, far beyond what they would have if they were as free to move in the earth beneath as in the space

above*; and though this deflection would coincide with that produced by the helix alone, still it was important to verify its effect. I therefore took a bar magnet 30 inches long, and weak in condition, and suspended the needle above it in various parts, so as to have the effect of north or south dip to any degree, or no dip at all near the middle parts. The effect of absence of air from beneath was also in a certain degree represented; and to make this point more striking, I occasionally put masses of iron on and under the middle part of the magnet. The results with the helix were now influenced greatly in the *amount* of the deflection, but not in the direction. When the helix affected the direction of the needle, it was according to the above laws.

2996. In the consideration of natural phenomena, the magnetic axis, and also the planes of the magnetic equator and meridian, being circles or planes of no deflection, are very important. Changing as they do with every change, either of place or declination or dip, they require some ready means of illustration, and can hardly be comprehended in their effects without a model. I have prepared a globe on which, after marking the places of the observatories, I have drawn the magnetic meridians of these places as they were last estimated. I have then in another colour drawn for each place its magnetic equator, making that a great circle parallel to the equatorial plane of the dipping-needle at the place. I have also marked on the globe the mean path of the sun for each month, and by the use of adjustible pins to indicate the hours before and after noon of any given place, I have the means of ascertaining with sufficient accuracy when the sun is in any particular quadrant, or what part of the quadrant; when it passes a neutral line, and what its position in relation to the place of observation is, in a manner which no diagrams or figures could supply. I have found the globe very useful; and I accustom myself to place it always in a certain position, namely, with the axis of rotation horizontal, the north pole to my right hand, and the astronomical meridian of the place of observation towards the zenith. The observer can then regard it as from the place of the rising sun.

2997. Though we thus have the experimental conditions of a needle under an action like that resulting in nature from the presence of the sun (2920.), I do not pretend that they can be applied without modification to natural phenomena, but only that they give very important aid in the study of the latter and the rationale of their action. The atmosphere, instead of being illimitable, wraps the earth round as a garment; the influence, as it extends from the region of action, must, in respect of that portion which is conveyed through its mass (2920.), curve with its curvature, and give a result in any particular place, which only refined calculations founded upon careful observations can determine accurately. In regard to the development of the air action, it would, I think, be very interesting to ascertain, even roughly, the

* Referring to the typical globe of cold air (2874.), it is manifest that if the space below the horizontal lines *a*, *c*, &c. were occupied by matter holding the lines in it, then the deflections now represented on the lower parts would appear above the holding surfaces, and to a much greater degree, though extending downwards to a much smaller space.

daily variations of a magnet at the bottom of a deep mine, half-way up, and at the mouth of the shaft. The results might tell us much about the holding power of the earth and the depths to which the deflections of the magnetic lines of force penetrate, and might even give us a rough expression of the changes of the internal power (or the absence of such changes) when freed from those dependent upon the atmosphere.

2998. Another reason why the experimental results must not be applied too closely is as follows. If the lines of force of the earth were perfectly regular, then the change produced amongst them by the sun and air would be regular also. But as the natural system is not regular either between the tropics, as at Sister's Walk and Longford in St. Helena, or in the higher latitudes, as at Hudson's Bay, so apparent inconsistences may and must result. The probability is that the greatest irregularities in the arrangement of the earth's magnetism are in and near the surface of the earth, and that above they tend to adjust with each other into a more regular order. Still the irregularities must extend their influence very far upwards, so that the contortions of the magnetic meridians or lines of force are not likely to be effaced, or much diminished, at the region coinciding with the place of the atmosphere's effect.

2999. But though the lines are irregular in the large space affected by the sun, the result will be expansion of the whole as a system and diamagnetic polarity. The lines of force below will be affected by those above; and so, though a perfect similarity between different places is not to be expected, still the kind of change at the earth's surface is not likely to be so uncertain as it might at first appear. Therefore I believe the globe (2996.) will be found very useful in giving information regarding the probable effects at the magnetic meridian and equator, due to the place of the sun in the two chief quadrants for any given month of the year, or hour of the day.

3000. The passage of the magnetic meridian is important, and appears far more so after the experiment described (2978.) than it did on a former occasion (2942.). Being very often inclined to the astronomical meridian, it must have great influence in deciding when the daily declination changes in its direction. The place of greatest action, and its travelling north or south along a line of magnetic force according as the declination was west or east in relation to the helix as a sun, was confirmed by an experiment; and the further observation (a consequence of the former), that when the sun was equidistant from a place more north or south than itself, its action was far stronger on that side at which its path and the declination direction made an acute angle than on the other side where it was obtuse, was also confirmed. Thus if the helix, moving from east to west, were passing a place north of it having western declination, then the action was stronger on the western side of the place than on the east for equal distances of the helix from the magnet.

3001. The passage of the magnetic equator by the sun is also important, since the direction of the diurnal variation of the experimental needle is then altered; and this is of the more consequence, because by the great degree of natural declination in many

places, even far north and south, this passage is thrown forward towards the astronomical meridian, either on the east side or the west, and comes into effect during the more influential hours of the sun or the cold. In all those places too where the dip is little, as at St. Helena, and in or near the sun's path, it may be important in influencing the amount of action. From the change of place of the sun between the tropics, and the variety of dip and declination at different places, the passing of the neutral planes by the sun and acting region must take place under an extreme variety of conditions; the unravelling of which I think will be much assisted by knowledge such as that which the preceding experiments and principles give. The sun may be astronomically either north or south of the needle, and yet the declination of the needle not change in direction (2980.); or if there were much mean declination, as at Greenwich, then it might be astronomically east or west of it, and yet the declination produced not change its direction. The sun region may be south of a place and yet send its upper end further south (2990.); for all will depend upon its position in relation to the magnetic meridian and the magnetic axis, which are in most cases very far removed from those that are astronomical: added to all these causes of variety, there is the fixation of the lines of force in the earth (2919.), which tends to give a further diversity to them.

3002. In the former paper I considered only the effect of air raised in temperature above the mean condition (2895.), illustrating it by the sun's effect in the middle of the day; *now* I purpose considering that which will be produced by the cold of night, which reduces the air of a given region below the mean air temperature of that place. When a portion of air is so cooled, its conduction power is increased; in conjunction with the warmer air of surrounding regions it deflects the lines of magnetic force passing through both, as indicated by the type globe (2864. 2874.), and acquires what I have called conduction polarity (paramagnetic), meaning thereby simply that the lines of force draw together in the middle of the cooled air.

3003. Theoretically, the effect of a cold region of air coming up from the east would be to make the magnetic lines of force, as they leave the earth, advance or bend towards it, because those in and about the cold air are inflected into it; and as those immediately west of the cold region move into or towards it, so those further west, being in part relieved from their tension, will also move east, and thus an effect, the reverse of that of the sun (2877. 2972.), or the same as that of the helix in the paramagnetic position (2973. 2994.), will be produced. The upper ends of needles at places having dip show this deflection of the upper part of the lines of force, because they move by, with, and in them.

3004. So as cold approaches, the lines will lean towards it until it is in the position of maximum action in the eastern quadrant; then they will return (in declination) before the cold, until both it and the line (or needle) are in the magnetic meridian; after which, as the cold travels on westward, the needle will follow it west until the cold has attained its place of maximum action in the west quadrant (2982.); and then,

as the cold retreats, the needle will return east to its mean place; assuming that there is no other action for the time than that of the cold region. The upper end of the free needle, therefore, at any given place will tend *towards* the cold region, just as before it tended *from* a warm region; and as the declination is affected, so also the inclination will be. If the cold be on the magnetic meridian of a place within the tropics, as St. Helena or Singapore, it will increase the dip there, whilst at the same moment it is diminishing the dip at places south or north of it having considerable dip, a result which follows directly from the inflection of the lines of force into or towards the cold region.

3005. The chief regions of heat and cold on the same parallel of latitude, do not follow each other at equal intervals of time. It is difficult to make a judgement regarding their interval in the atmosphere above; but the maximum of cold on the earth for the twenty-four hours, is assumed by many as being seventeen hours after the preceding noon, and only seven hours from the coming noon. This brings into consideration the joint effect of hot and cold regions in deflecting the lines of force, especially during the forenoon and middle of the day. If a cold region be only three and a half hours west of a place at the same time that the warm region is three and a half hours east of it, it is very manifest that the joint effect of the two, for both act then to cause the same deflection, will be far greater than that of the heat or cold alone, or than any corresponding effect at other periods, for neither twelve hours after, nor at any other time, will there be an equivalent condition of circumstances; and so it is also for other combinations of hot and cold regions, the effect of which will vary both by position and by their extent. A free needle is held in tension by the lines, which are themselves governed by the hot and cold regions of atmosphere; it probably never occupies its mean place, but is always in the resultant of these ever-present and ever-varying causes of change.

3006. As the earth revolves under the sun, each place would have, speaking generally, a maximum and a minimum of temperature for its atmosphere in the twenty-four hours. But looking at the globe as a whole, there would be one maximum and two minima, *i. e.* there would be a maximum region somewhere beneath the sun in his path, and a minimum in each of the polar regions; which, as regards the twenty-four hours, would not be at the pole, but in some place of high latitude, and perhaps, as before, seven or eight hours before noon. These cold regions will be very seriously affected in their extent and place and power by the position of the sun between the tropics; for as he advances to one tropic the cold region there will diminish in extent and force, whilst the other will grow up in importance; and whilst they thus vary in their power of influencing the general direction of the lines of force, they will vary in their own position also, and have at different times very various relations of place to the sun in different months, and so produce very various effects. It is these differences which are made manifest to us, as I believe, in the night and morning actions at the numerous observatories scattered over the globe.

3007. I will proceed to apply these views, and the additional knowledge gained by experiment, to the localities formerly considered, and to some new ones between the tropics, for the purpose of explaining, if I can, the principles of night action; of retardation, more or less, of the effects in relation to local time; of the difference in direction of the declination variation in different months, for the same place at the same hours, as pointed out by Colonel SABINE; of the diminution of dip in one place, and increase of it at another for the same local time. In doing so, it will be necessary to refer continually to that place which may be considered, in respect of the station, as the centre of hot or cold action for the time. I will endeavour to use the word region for that purpose, meaning thereby not the whole extent of heated or warmed air, nor the centre, but the chief place of the altered portion. It is very manifest that in some days in March or September, *all* the air that is east of the meridian at 21^h or 22^h may be considered warm in comparison of that which is then west of the same meridian, and that a resultant of action, which shall be the same for all places, cannot exist.

3008. We are to remember that the eastening and the westening of the upper end of the needle, of which I always speak, is produced in two ways. The needle travels as positively by the withdrawal of a direct cause of action as it does under the immediate direct action of that cause, but in the contrary direction (2982.). A westening may be the result either of the coming up of the sun on the east of the place of observation, or of its withdrawal in the west, after he has passed over the meridian and produced the great east swing.

3009. *St. Petersburgh* has a mean declination of 6° 10′ W., and a dip of 70° 30′ N.; therefore, though the magnetic and astronomical meridians are not very oblique to each other, still the sun or warm region reaches the former from 20′ to 40′ before the latter, and hence the time of the great sun-swing, which is from 20 to 1 o'clock, is made earlier than it otherwise would be. The magnetic equator of the needle (2977.) forms an angle of about 40° with the earth's equator, and being thus tilted, it disposes the two quadrants chiefly concerned in the daily variation (2979.), so, that in the St. Petersburgh summer the warmest region is not only far nearer to the needle, but passes through the strongest places of action of the quadrants, whereas in winter it is further off, and also in much weaker positions. Hence a cause, as I believe, of the great difference in the amount of variation of declination, and also in its character: in November, December and January, it is from 4′·47 to 4′·65 only, whilst in June it is 11′·52*. See the Tables, p. 82, and the Curves, Plate II.

3010. In December or January, being St. Petersburgh winter, the sun-swing east

* The eastening and westening of a free dipping-needle are not properly represented by the movements of a horizontal needle, inasmuch as at places with different dip the angle is read off on planes differently inclined to the dip itself, and in high latitudes the effect is greatly exaggerated. But though different places may not be compared without a correction, the variations for the same place as St. Petersburgh are comparable and proportionate.

almost disappears. It is over by 1 o'clock*, after which the upper end of the needle follows the sun until 9^h, having passed its mean position at 5^h. It then stops, after which it moves east until 16^h or 17^h; then again stops, or nearly so, until 21^h, and then the sun-swing comes on, carrying it to extreme east. So here there are two very important points to explain, namely, why the needle moves eastward after 9^h, and why it does not travel westward from 13^h to 20^h, but, on the contrary, is travelling eastwards or standing still: the explanation, according to my view, is as follows:—St. Petersburgh is a place in which, from its position, the upper cold, consequent upon the daily withdrawal of the sun, would produce a paramagnetic action (2994. 3003.). This action, as the sun set, would begin to appear on the east, and I conclude that at 9^h–11^h the cold region coming up from the east, not on the latitude of the sun's path, which is far to the south, but probably near to that of St. Petersburgh itself, is able at 9–11 o'clock, during which the needle is stationary, to counteract any remaining tendency westward, and after that to draw the line of force and the needle end eastward until 17 o'clock, and to hold it there, after which the sun sends it eastward in the great swing. That the cold, considering its probable position, may well direct the needle end eastward till 17^h, and the sun region not send it westward from 17^h to 20^h or 21^h, is seen, I think, to be a very natural consequence of the probable position of the two regions between these hours. For letting the sun (whose place we know) represent the warm region at 17^h, he is then in the eastern quadrant below the horizon, so that if he could affect the needle through or round the earth (2995.), it would be to easten it, and it continues in that quadrant until 19^h. Then at 19^h, when he enters the quadrant, in which he begins to exert a westening action on the sun, he is in such a position as respects the needle at St. Petersburgh (as is seen by a line drawn over the surface of the globe (2996.) and compared with the magnetic meridian and dip), and in so inefficient a part of the quadrant (2982.), and also so far off, that it has no power to send the needle westward, but only in association with the retreating cold region to hold it there, until at 21^h, or thereabout, the sun-swing from west to east occurs as in other cases. After this the needle follows the sun from 1 o'clock, being, as the hours advance, gradually arrested and taken up by the cold region of the next twenty-four hours, as already described.

3011. I have considered the cold eastening as continued until as late as 17^h, which would imply probably that until that hour the cold region was east of St. Petersburgh. It is very difficult to speak, even in a general manner, of the places or times of things so little identified as yet, as the warm and cold regions in the upper atmosphere; but referring to the temperatures on the earth at St. Petersburgh, I may point out, that the extreme cold is, in the month of January, as late as 19 and 20 o'clock, and *five hours* later than it is in the summer months. I may also point out here, for use in the summer months, that the maximum heat varies three hours in the *opposite direction*; so

* The St. Petersburgh observations are at 21½ minutes after each hour; but I mention the hour without the minutes as sufficient for a general statement.

that whilst from the highest to the lowest temperature in the day is only eleven hours in summer, it is nineteen hours in winter, as may be seen by the Temperature Table, p. 83. As the day comes on, therefore, in January the highest temperature is only five hours after the lowest, which accords generally with the assumed cause of the effects on the needle*.

3012. As I am endeavouring to make St. Petersburgh a general case of night action for the explanation of corresponding effects at other places, so I may notice that the night action must contain a portion of sun effect which combines with that of the cold. The action of the sun is known by observation to be very extended; in the case of St. Petersburgh, the sun, when at the southern tropic and on the meridian, is between 80° and 90° from the station, and yet we see by the observations and curves how large an effect he produces (3009.). Wherever the sun may be, he is by his motion causing changes which are felt simultaneously over the whole globe; and at 9 and 10 o'clock he is in an effectual part of that quadrant which would send the needle eastward if the earth were replaced by air, and in the representative experiments with a helix (2995.) does so send it eastward when a magnet is interposed. The night action ought therefore to be greatest in winter, as it is, because the cold is then most intense, and also because the action of the distant sun coincides with it. It is very probable that many of the curious contortions of the night action which appear in the curves of Hobarton, Toronto and elsewhere, may depend upon the manner in which, at different hours, these two causes (probably with others) combine together.

3013. Though the declination varies little or nothing between 17^h and 21^h, no westening then appearing (3010.), still I should expect a marked action on the inclination at that time, and conclude that it will be on the increase; but I have not been able to obtain a table of the daily variation of inclination.

3014. In the month of February the same remarks apply; but as the sun is now coming from the southern signs and drawing nearer to St. Petersburgh its power is increasing, and this is shown by making the cold eastening for 15^h, 16^h and 17^h less in extent than before by more than half a minute (of a degree), and by absolutely overcoming it and making a return westwards between 17^h and 18^h, before the swing to the east comes on. In March the effect is still more striking; the paramagnetic eastening is arrested at 14^h, and the following diamagnetic westening extends to 20^h; then follows the swing. In April the westening by the warm region is as early as 13^h and continues to 20^h, being very strong. It is interesting to look at the Table of Temperatures for these months, even as they are obtained at the earth's surface. As the months

* In relation to the cold of the upper atmosphere and the occurrence of its maximum (at certain levels at least), not at midnight but hours after, how often do we in this country see a clear bright night, and then just before the sun rises, the formation of a veil of clouds high up, and, upon his appearing, their dissolution and passing away! In these cases the clouds show the time of greatest cold above by their formation, and by their dissolution its quick reversion and change into increasing warmth.

come on the eastening from the cold ceases sooner and sooner, being in January and April 17^h and 13^h respectively. The minimum of temperature also retreats, being for the same month 20^h and 16^h. On the contrary, the maximum of heat *advances* from the winter to the summer months, being also greatly increased; and the effect on the sun-swing is seen both in the *advanced* time of change and the *increased* amount of variation.

3015. In May and June the night or cold eastening has disappeared, or is shown only by a little hesitation; and from midnight the coming on of the sun region sets the needle end west. If we look at the globe (2996.), we should be led to expect that it would do this. The sun is then in the northern tropic nearly, wheeling round St. Petersburgh and comparatively near to it; and a free dipping-needle would in twenty-four hours make one revolution in the same direction as the sun region, but at the opposite end of the line, joining the two together. If the needle were at the astronomical pole of the earth, having great dip, it would describe almost a circle with nearly uniform motion; but being really much nearer to the warm region in one part of the uniform daily course of the latter than another, the radius vector joining it with the region then makes a much greater angle in a given time than when it is further off, and hence the greater rapidity of the motion between 20^h and 1^h, and the production of what I have familiarly called the sun-swing from west to east.

3016. It will be seen from the Table of Curves (Plate II.), that we have at St. Petersburgh a fine example of that kind of result which Colonel SABINE called attention to so strongly in his paper upon the St. Helena phenomena*; and those occurring at Hobarton, Toronto and elsewhere; namely, a declination variation in *different* directions for the same hours in different months. Thus, in the present case, the needle end goes eastward for the hours 13^h to 20^h in October, November, December, January and February, whilst it goes west for the same hours in April, May, June, July and August: March and September curves fall midway. But this difference is now I hope by the hypothesis accounted for (3010. 3015.), and I trust that equally satisfactory reasons will appear for St. Helena (3045.) and other places (3022. 3039. 3065.).

3017. The paramagnetic character of the eastening effect by cold in the winter months after 10 o'clock, would probably be illustrated by inclination observations for the same time; for if the cold region passes to the south of St. Petersburgh the inclination will be decreased by the paramagnetic action, but increased by the diamagnetic resultant; and the manner in which these two elements of direction, *i. e.* inclination and declination, are combined at any given moment, is very important to the full elucidation of the magnetic effect of the atmosphere. I have not been able to give these data for St. Petersburgh. The total force variations would also help greatly to clear up the subject. Indeed it is not fair to endeavour to explain the results of the assigned cause by taking only one element of three into consideration. What we require ultimately to know, is all the changes of a free needle in position and in respect

* Philosophical Transactions, 1847, p. 51.

of power. All are important, and all should be considered at once. I presume that the theory of the variations cannot advance very far without their joint consideration.

3018. *Greenwich* presents a fine case of the night episode, and the different directions of the magnetic variation for the same hours in different months. In these respects it is very much like St. Petersburgh, but has great additional interest, because of the large western declination*, and the effect produced by it on the places of the active quadrants (2979. 3000.), and the times of the variation phenomena. On setting up its position on the globe (2996.), it will be seen that the equatorial plane is not likely to be much concerned in the midday action, and that the sun or warm region passes nearly across the middle of the two chief quadrants in summer; which with its nearness at the same time, ought to make the midday swing to east very great. In winter it is further off and in much weaker parts of the quadrant, so that the swing ought to be far less, and such is the case. The greatest summer variation is 11'·30, and the least winter variation only 5'·88. In April, May, June, July and August, the great west declination of the south or upper end of the needle is at $19^h\ 20'$, and the chief east position at $1^h\ 20'$. The latter position remains the same all the year round, but the extreme westening is in the other seven (cold) months at $9^h\ 20'$ and $11^h\ 20'$†, or verging towards midnight; it then surpassing the morning west deflection. Thus the sun's effect in summer, in weakening the cold night effect (3005.), is very evident; and so also is the manner in which the night action grows up, until very prominent, in the winter months, through the strengthening of the cold action (3006.), when the sun is towards the southern tropic and in the weaker parts of the segments. The assumed principles of this action have been already given in the case of St. Petersburgh (3010. &c.).

3019. The magnetic meridian is much to the east of the astronomical meridian, where the warm region passes it, especially in winter, for then the sun crosses it about 10 o'clock, and in summer about 11 o'clock. Hence the swing ought to be earlier in winter than in summer, though, because of the slower angular motion of the warm region in relation to Greenwich (3015.), it ought then to occupy a longer time; and yet, as above said (3018.), be, by reason of distance, of smaller amount. All this appears to accord remarkably with the fact. The swing begins at 17^h in the winter but not until 19^h in the summer, and ending at the same hour at both seasons, namely, 1 o'clock, is much longer in its occurrence in winter than in summer. It begins earlier, because the magnetic meridian is sooner passed than in summer; and the reason also appears why the extension in time is at the beginning rather than at the termination of the swing; for, because of the declination, the warm region is at the same hours much less east of the magnetic meridian in the morning and much further west of it

* Mean declination 22° 51′ W. Mean inclination 69° N.

† See the Curves, Plate II. The observations are only for every two hours, so that no degree of nicety can be expected in assigning the time of any given change.

in the afternoon, in winter than in summer; hence the swing is thrown forward in time in winter; and though prolonged, its termination coincides with the termination in summer, as far at least as these two-hour observations can indicate.

3020. As the region precedes the sun, the degree of mean declination here ought to make the day-swing come on early, *i. e.* earlier than at Hobarton, and especially earlier than at Toronto, unless other causes of variation interfere. Now the beginning is earlier than at Toronto, but the end the same. Both the beginning and the end is an hour earlier than at Hobarton. The latter difference I believe due to the difference of mean declination: at Toronto, I think we shall find another cause influencing the time (3032.).

3021. We are to remember also that in winter the sun or warm region passes the magnetic meridian two hours before he passes the astronomical meridian; and therefore his effect in giving west position to the south or upper end of the needle ceases long before it does in summer, and perhaps even before it ceases to come nearer; and so the eastern after-effect on it ought to be greater, which it is. This eastern effect should be strengthened also, because the action of the warm region on the needle ought to be comparatively great after passing the magnetic meridian; for its path forms an obtuse angle with the meridian before the passage and an acute one afterwards (3000.), and therefore is more powerful. To all these causes of action will be added the effect for the time of the cold in the distant west (3005.).

3022. The case of difference of direction before 19^h (3016.) is very marked at Greenwich, as may be seen by looking at the Curves for the months, Plate II. The south or upper end of the needle goes west in May, June, July and August, from 12^h to 19^h, *i. e.* from midnight to five hours before noon; but in October, November, December and January, it is eastening at the same hours. Considering first a summer month, as June, the upper end of the needle is westward as the sun comes onward (as it ought to be) until 19^h, when he is almost in the middle of his passage through the east quadrant; and in respect of distance and angular relation to the magnetic meridian, the warm region is then, probably, in the place of greatest power to produce westening of the needle end*. In the next six hours the needle passes to extreme east, performing, according to the observations, a fourth of the whole swing in the first two hours, a half in the next two, and a fourth in the remaining two, the journey being no doubt with first rapidly increasing and then rapidly diminishing velocity. In this transit of the region, the sun is for about two-thirds of the time in the eastern quadrant, and one-third in the western; and his path in the latter third forms almost the base of an equilateral triangle with Greenwich, having the magnetic meridian for one side, so that all that time it is close to and therefore has strong action on the needle (3000.). The sun is at 1^h in such a position as respects this angle, that if

* It must not be forgotten, that the return from an extreme east or west position is not when the sun or warm region passes by a neutral line, or from one quadrant to another, but when it passes its point of greatest action in a quadrant (2982.).

we assume the region to be somewhat in advance of it, the latter would be in that place where it could exert its maximum eastening effect; and therefore after that, as it recedes westwards, would let the needle return from east to west, as it does, following it. The needle continues to go west, passing its *mean* place for the month about 7^h; in the meantime, before that, at a little after 6 o'clock, the sun has left the western segment by passing the magnetic equator; it has not yet set to Greenwich, and if it have any action, it will, because of the segment it is now in (2979.), still be to carry the needle end *westward*. The end in fact continues to go westward, slowly only, after 10 o'clock, gaining a little from 10^h to 15^h; and then, as the sun comes up, passing more rapidly west, as it ought to do, until 19^h, and finally making the great swing to the east as before. The whole progression here is very simple, and apparently a natural result of the assumed cause. Effects of cooling no doubt come in; but the cold region has diminished in intensity and extent (3006.), has retreated northward, and its action appears in combining with the former to produce only variations in the velocity of the change.

3023. Then for the winter, let us consider January; and, as the eastening is a maximum in all the months at 1 o'clock, after the sun's passage across the meridian, let us begin the cycle there. At 1^h the upper end of the needle is at extreme east, and the amount of the variation not half what it was in summer, the sun being now far off. The sun and warm region pass the magnetic meridian about 21^h or 22^h; and therefore, in the hours before and after that, should produce the full west to east effect. At 1 o'clock the needle returns west, following the retreating sun, and does so quickly for seven or eight hours, or up to 9^h, during which time the warm region, and also the early morning cold region, are in quadrants and positions, which, if they have any action at all like that referred to in the experiments (2975. 2995.), would then set or hold the needle end west of its mean position. Then an action of the following kind supervenes; the needle remains stationary until 11^h, after which it goes east at midnight and until 15^h; again remains stationary, or nearly so, for two hours; then eastens again, slowly at first and afterwards more rapidly, until 1^h, when it has attained its maximum eastening and the place from whence it set out.

3024. This night action is another case of the action of a cold region like that considered in respect of St. Petersburgh (3010.). It appears to me that at 11^h the immediate sun action and returns west after it, were over; that the cold region which was coming round from the east did then act by its paramagnetic condition (combined with the complementary effects of the sun's action on the other side of the globe), and set the needle eastward, as it would be competent to do (2994. 3010.) until 14^h or 15^h. In eastening, the needle does not arrive at the mean place, but is still $1'$ west of it; and the reason why it hangs there from 15^h to 17^h and then begins to go east again, more and more under the sun's action, is probably that, as the sun rises in the southern tropics, his distance and position bring the resulting distant

warm region gradually into action with that of the nearer cold; that at first he stops the action of the latter, and then as he advances combines with and finally replaces it; causing the usual swing to come on, slowly at first and then quickly, from west to east by 1^h. How this would happen is well seen, both as respects the place of the sun in the southern hemisphere, and in the two magnetic segments, by reference to the globe (2996.) and the diagram of the curves of variation, Plate II.

3025. Considering another and an intermediate month as March; at 1^h the upper end of the needle is at extreme east; then until 9^h it follows the sun as before (3023.). From 9^h to 11^h it is stationary; then the paramagnetic action of cold from the east occurs, and the needle moves east until 13^h. It is then stopped, and two hours sooner than before; for the sun now appears to Greenwich as early as 6 o'clock, and in a more favourable position for effect, both as regards the magnetic meridian and the segment in which it has for the time its place; and so the needle is actually sent west for a couple of hours. It is then almost held steady until 19^h, after which the great sun-swing occurs. The holding west and yet the absence of more westening between 15^h and 19^h, is not inconsistent with the southern place of the warm region, and it is probable that at that time the *dip* is increasing; an effect which would accord very harmoniously with the condition of matters at the time.

3026. Other months are on this or that side of March in respect of their effects; the corresponding month on the opposite side of the year (September) is the same as March, except in that portion of effect which is consequent upon a month following one that is warmer or colder than itself (3053.). Greenwich therefore satisfactorily illustrates the application of the hypothesis to the case of a difference in direction for the same hour in different months (3016. 3022.); and also the occurrence of the night effect, and its transition into the very marked eastening of the early morning.

3027. The cases of *Hobarton* and *Toronto* are so similar, though in opposite hemispheres, that they may be considered together. A very important comparison of the phenomena at both places has been already made by Colonel Sabine in relation to the variations of declination, inclination, and total force*. When examined by the globe (2996.) the distribution of the quadrants is nearly alike, the sun being in two chief east and west quadrants, from about 18 to 6 o'clock, or during the day. The sun is in more influential parts of the quadrants in summer than in winter, and the effect is seen in the difference of the amount of declination variation. At Hobarton it is $12'{\cdot}05$ in summer and only $3'{\cdot}6$ in winter. At Toronto it is $14'$ in summer and $5'{\cdot}2$ in winter. The night action at both is alike in character, and has been sufficiently explained according to the hypothesis in the former cases (3010. 3024.).

3028. Colonel Sabine has given the data by which the variations of the inclination and of the total force at Hobarton and Toronto may be compared with and applied to the hypothesis; but I hesitate to enter upon them in this general view, inasmuch

* Hobarton Observations, 1850, vol. i. p. lxviii., &c.; also Philosophical Transactions, 1847, p. 55, and 1850, pp. 201, 215, &c. See the Curves, Plate II., and Tables for Toronto, pp. 80, 81.

as these and the declination variations should be closely considered and compared together at every hour for each particular place. The inclination variation at Hobarton is greatest in its summer, being then 2'·18, and least in winter, or 1'·28, as was to be expected. The great variation occurs in the daytime, as with the declination; the dip being most as the sun region passes over the meridian. The greatest dip is not at the same hour for all the months; it occurs at 23 o'clock for December, February and March, at 24 o'clock for September, at 1 o'clock for June and July; as it moves on so do the points of least dip on each side of it, so that the whole curve advances in time in the order of these months. There is also another affection of it, for the *quickest* transition is from *most* to *least* dip in some months, as December, February, and from *least* to *most* dip in other months, as June, July, September. At Toronto the dip variation, though peculiar in some points, may be said to have the same general character.

3029. For the variation of the total force at both places, I will at present only refer to Colonel SABINE's volumes, and the observations he has made thereon.

3030. There is a remarkable difference between the time of the day changes at Hobarton and Toronto, to which Colonel SABINE has called attention. It consists in the occurrence of those at the latter place, about an hour before those of the former. If this had depended upon the declination, then the change should have taken place first at Hobarton, for there the sun arrives at the magnetic meridian before he comes to the astronomical meridian, and for like hours of local time he is in a better position in the quadrant in the afternoon than at Toronto; still it is the later of the two.

3031. If the *time* of the sun-swing from west to east be considered, the middle of it ought to be somewhere near the period when the warm region is passing the magnetic meridian (2982.), and in that way supplies an approximative expression of the relative positions of the region and the sun. The swing is at Hobarton from 21 to 2 o'clock, or five hours, and the magnetic meridian is passed by the sun nearly in the middle of the time, or $23^h\ 20'$ o'clock. But according to the supposition just made, this is also the time at which the warm region ought also to pass, and so the sun and the region in this place appear to arrive at the meridian together. At *Toronto* the sun-swing is about four hours in winter, or from 21 to 1 o'clock, and five hours in summer, or from 20 to 1 o'clock. Of the latter five hours the middle is $22\frac{1}{2}$ o'clock, at which time the region ought to pass over the magnetic meridian, and as that coincides nearly with the astronomical meridian, it appears that the region is about $1\frac{1}{2}$ hour *before* the sun. By a similar comparison for winter, the region would then appear to be about an hour before the sun*.

* In reference to the position in advance of the sun, of the resultant of those actions which set the needle end westward, we must remember that the preceding cold, being perhaps seven hours only to the west, is by its action on the general system of the curves aiding the westening of the needle, whilst the sun is in the east and even over the meridian (3005.).

3032. I am inclined to refer much of this precession of the warm region at Toronto to the geographical distribution of land and water there. The Atlantic is on the east and the continent of America on the west of the station, and as Dove's charts and results intimate, the temperature may rise higher and sooner over the land than over the water, and so throw the warm region in respect of Toronto in advance of the time or of the sun. In the case of Hobarton the arrangement is different; and, in fact, what land there is is between the advancing sun and the station, and would tend to hold the warm air region back, and tend to cause its time to coincide with that of the sun. Even the greater difference in summer than in winter at Toronto appears to be explicable in the same manner, by reference to the relative position of the sun at the two seasons to the land and water arrangement.

3033. Though the temperature on the earth's surface is a very uncertain indication of that above (2937.), yet as far as it goes it harmonizes with this view. The maximum temperature occurs sooner after midday at Hobarton than at Toronto; in the former place it is at 2 o'clock and very regular, and the minimum at 16–19 o'clock, being earlier in summer and later in winter. At Toronto the maxima are from 2 to 4 o'clock, and the minima at 16–18 o'clock. The maxima are later in summer than in winter; the minima are as at Hobarton, being later in winter than in summer. The mean temperature is lower at Toronto than at Hobarton, being as 44°·48 and 53°·48: the range of variation is also greater, being at Toronto 43° and for Hobarton only 18°.

3034. It is probable that effects of retardation and acceleration, in respect of the passage of the local part of the warm region for a given place, may occur in many parts of the globe, and these will require to be ascertained for every locality and for the different seasons there. A place having the reverse position of Toronto would have a reversed or retarded effect; and hence it might happen that needles in the same latitude might be affected at very different local times, and yet all be regularly affected every twenty-four hours. The region would in that time make its diurnal revolution, but vary in the velocity of its different parts at different periods of its journey, and that in a different degree and order for different latitudes, and for different parts of the same parallel of latitude. Even the time during which the effect (as for instance the sun-swing) continued would probably be altered; one place holding the influence longer and another dismissing it sooner, analogous to two conditions of stable and unstable equilibrium.

3035. *Cape of Good Hope**.—This station is in longitude 18° 33′ east and latitude 33° 56′ south. The mean declination is 29° west and the dip 53° 15′ south. The amount of dip, combined with the position of the place, gives a magnetic equator, which passes nearly through the astronomical poles, and so the sun's path in every part of the year intersects it almost at right angles and at the same hour, namely, about 20′ past 7 o'clock in the morning and evening, or at $19^h\ 20'$ and $7^h\ 20'$. But

* See Tables, pp. 117, 118, and curves of variation, Plate II.

because of the great declination, the sun is in the astronomical meridian two hours before he arrives at the magnetic meridian in Cape winter, and half an hour or more before in Cape summer.

3036. The sun passes obliquely through both the chief quadrants and across their central parts pretty equably; but because of the western character of the mean declination he is much nearer the Cape when in the eastern than when in the western quadrant for all the months, and so the coming up effect, *i. e.* the westening before the midday swing commences, ought to be more powerful than the eastening after it is over, and such is the case. This is in beautiful and striking contrast to Greenwich, which, having the same kind of mean declination and nearly in the same degree, is on the north of the sun's path, and therefore the luminary passes its magnetic meridian before 12 o'clock, and for a time still approaches the station: the result is the reverse effect to what we have at the Cape; for the eastening effect at the end of the midday swing is more powerful than the westening effect before it, as is well seen by the curves given in Plate II.

3037. Selecting July as the month in which the effect of winter occurs at the Cape, we find that the day-swing is very feeble, as it ought to be, the sun being in the northern tropic and far away; and the swing east is at an end by 3 o'clock, when the sun has passed by about one hour over the magnetic meridian. The upper or north end of the needle then westens for two hours, following the sun until 5^h, when the luminary is low to the Cape and at its setting. After that the needle end eastens slowly until 10^h, then a little more quickly until midnight (passing the mean position at 11^h); quicker still until 16^h or 17^h, and still more quickly until 19^h, when it has attained its maximum east position. This effect I believe to be due to the cold, which in these hours is approaching from the east, and setting by its paramagnetic action (3003.) the needle end eastward. On the surface of the earth the maximum cold in this month is at 17^h or 18^h, and as far as it goes this result accords with the effect above described. At 19^h, the sun in rising not only stops the eastening but quickly drives the needle back again, and the latter very rapidly goes westward until about 23^h, at which time the sun-swing from west to east comes on, being over by 2^h or 3^h, completing the daily variation, after which the needle goes west, following the sun as before. In this sun-swing is seen the effect of an inclined magnetic meridian (3000.); for though the sun is, at the beginning, only an hour east of the astronomical meridian, he is full three hours to the east of the magnetic meridian. As the swing occupies about four hours, the warm region is probably near the magnetic meridian about half-past 12 or 1 o'clock.

3038. *January* presents a case of Cape summer. The day-swing is then from 21^h to 1^h or 2^h. After 2^h the needle upper end follows the sun westward until 6^h, and then moves a little eastward for two hours; after this it moves slowly westward again, the whole effect being as if a cold region had occurred on the east, had passed over and gone away west, and the temperature below at this time is within 2° of the

minimum. This night effect of drawing the needle westward (3004.) proceeds slowly until 15^h or 16^h, being assisted by the rising temperature on the east urging the end still more rapidly west until 20^h, when having reached its maximum in that direction, it at 21^h turns back and is driven to extreme east in the sun-swing, through an amount of variation more than twice as great as that produced in July or Cape winter.

3039. I think the above is a true explanation of the reverse motion of the needle in the months of July and January, or Cape winter and summer. In winter the paramagnetic effect of cold air is on between 12^h and 19^h, remaining longer on the east side of the magnetic meridian; as it passes forward, both it and the sun region conspire at 19^h to carry the needle westward, for though they have opposite actions they are then also on opposite sides of the magnetic meridian (3005.). In the summer the cold region has much less power, occurs earlier*, soon passes over, for the summer sun is behind it, and then rather aids the sun in carrying the needle westward.

3040. Some of the other months are still more striking in summer effect. February has a swing through 8′ from west to east between 21^h and 1^h; then from 1^h to 3^h it scarcely changes; from 3^h to 6^h it follows the sun west; from 6^h to 16^h it varies but little, showing the merest trace of east effect about 8^h; and after 16^h it passes west more and more rapidly, so that by 21^h it is at a maximum west, ready to swing back as the sun region passes over. The other and intermediate months are easily traced, and found to be beautifully consistent with the same principles of the hypothesis. As is evident, in almost every case each month partakes of the character of the preceding month in some degree, though not so much in this case of the Cape as in some others (3053.). The curves of December and January are more equal.

3041. The time of the sun-swing illustrates exceedingly well the effect of the inclined magnetic meridian (3000.). In November, December and January, the swing is from 20^h to between 1^h and 2^h. In these months the sun crosses the astronomical meridian about half an hour before he arrives at the magnetic meridian. In October, February and March, the swing is later, being from 21^h to 2^h or 3^h, for the sun then passes the magnetic meridian an hour or more later than the astronomical or time meridian. In September, April and May, the swing is still later, being from 22^h to 2^h or 3^h, and the sun is still longer than before in reaching the magnetic meridian. In June, July and August, the swing is latest, being from 23^h to 3^h, and the sun is proportionately late in arriving at the magnetic meridian. What I describe as the passage of the sun is of course true of the warm region which precedes it; but I prefer referring to the visible type rather than to the invisible reality, because it ties the considerations of time more simply together.

3042. The inclination at the Cape varies singularly in the twenty-four hours, depending, I think, upon its mean degree. It is such that the warm and cold resultants of action for the Cape will sometimes be above the line of the dip and sometimes

* The minimum temperature below is three hours earlier.

below it, not only for different times of the year, but I think in some seasons, even at different times of the day. It would require much attention to unravel the whole effect. In June, July and August, when the sun and its warm region are greatly to the north of the Cape, it appears that the dip is increased as the region passes, which would give a rotation of the upper end of the needle like that at Hobarton (2909.); but in November, December, January, February, March and April, the dip diminishes at that time, and the resulting rotation of the pole is of the contrary kind, or like that at St. Helena (3057.) and Singapore (3061. 3067.).

3043. The daily variations of intensity at the Cape are remarkable. In the months October to April it is at a chief maximum at 19^h or 20^h; by noon it is reduced to a minimum as the sun passes over; gradually rises to a second maximum about 4^h or 5^h, and then, after sinking a little about 8^h or 9^h, reaches the chief maximum about 18^h or 19^h next morning. In the months from May to September the chief maximum is at 21^h or 22^h, which is followed by a minimum at 1^h or 2^h, due to the day effect. Then comes on the 5^h maximum, and after thirteen hours or more the second minimum as low almost as the former, and only three hours before the chief maximum; so that this maximum is placed between minima close on each side of it.

3044. These are exactly the months during which the upper end of the needle moves eastward in early morning up to 19^h, and that is just the hour when the minimum intensity occurs. From 18^h or 19^h to 21^h the intensity rises to a maximum, precisely as the lines of force are moving westward before the sun region, prior to their quick return east; and as they return in their quick journey so the intensity falls to a minimum again, and is at that minimum at 1^h or 2^h, just as the swing is over. Here is a very close connexion, and it is curious to see the needle end at east with minimum power at 18^h, and again also at 1^h, remembering that in that time it has swung from east to west and back to east again.

3045. *St. Helena**.—This is a station which Colonel SABINE has distinguished as of the highest interest; being near the line of least force, within the tropics, and with little magnetic inclination†. It was here also that he called attention to the striking fact, that the course of the needle is in some months in one direction, and in other months in the contrary for the same hours of the day‡. DE LA RIVE attempted to explain this fact§, but SABINE has stated that this explanation is not satisfactory¶.

3046. St. Helena being a small island in the south Atlantic ocean is removed about 1200 miles from the nearest land. The longitude is 5° 40′ west, the latitude 15° 56′ south; the mean declination 23° 30′ west, and the mean dip 22° south. Hence there are three quadrants concerned in the day action of the sun, especially when that luminary is south of the equator. The sun is south of St. Helena itself in the months

* See Tables, pp. 119, 120, and curves of variation, Plate II.

† Magnetical Observations, St. Helena, 1840 to 1843. ‡ Philosophical Transactions, 1847, p. 51.

§ Annales de Chimie et de Physique, March 1849, tome xxv. p. 310.

¶ Proceedings of the Royal Society, May 10, 1849, p. 821.

of November, December, January and February, or for nearly that time; it is north of the island for the rest of the year. At one time the sun passes the astronomical meridian before it arrives at the magnetic meridian, and at another time the contrary is the case. In addition to these peculiar circumstances, St. Helena is a place of great local differences, and also its dip is so low that the sun's day effect is almost constantly to depress and lessen it.

3047. In June and July the sun rises to St. Helena in the south-east quadrant; about an hour after it passes into the north-east quadrant, and crosses it towards the southern end, being then at mid-distance in the quadrant about one-third of the length, or nearly 60° from the southern termination. It leaves this quadrant about $1^h\ 20^m$, crossing the magnetic meridian at that time (and consequently so long *after* passing the astronomical meridian), and entering the third or north-west quadrant traverses it obliquely towards its northern extremity. In our winter, December and January, the sun also rises to St. Helena in the south-east quadrant, as before; but it now remains in it until 22^h, being for much of the time in strong places of action; it enters the north-east quadrant to the south of St. Helena, and does not remain in it two hours, being then only in the weakest part of it; it leaves it again *before* arriving at the astronomical meridian, then enters the north-west quadrant, gliding along near to its southern side, and is within two-thirds of an hour of leaving it when it sets to St. Helena.

3048. As June presents the aspect of circumstances approaching nearest to that of a station further south, as Hobarton or the Cape, so I will consider the variations for it first. The north or upper end of the needle is then nearly at its mean place at midnight or 12^h: it advances east (slowly at first) until 16^h, and then more and more rapidly up to 19^h, when it stops and goes as quickly west until about 22^h, after which it changes but little until 3^h, when it moves *west* till 5^h, and then slowly east up to 12^h, and then onwards to 16^h and 19^h, as already said. The eastening from midnight, and before I refer to the paramagnetic action of the cold, which comes up from the east as before (3003. 3025. 3037.); the rapid increase of the eastening from 16^h to 19^h is consistent with the increasing cold of the early morning, and also with the circumstance, that the sun and its representative region are then passing from the south-east into the north-east quadrant, and must be not far from the neutral line, for that is the time of quickest transit of the needle. As the sun advances into the north-east quadrant, it first stops the eastening, as at 19^h, and then converts it into westening (3014.), which goes on consistently with all former observations until 22^h; the needle is then retained a little west of its mean position until 1^h, at which time it has not yet attained coincidence with the magnetic meridian, and after this hour it is determined east a little until 3^h. This effect, from 22^h to 3^h, I consider as the sun-swing to the east; and I think, examining the globe (2996.), its small amount in declination is quite consistent with the relative positions of St. Helena and the warm region, combined with those of the active and neutral parts of the quadrants traversed during the time. From 3^h to 5^h the needle end moves westward, following the sun; and

that effect harmonizes with the idea that the previous holding of the needle in an eastern position, from 22^h to 3^h, is the sun effect: then the slow eastening from 5^h to midnight and beyond, is the cold effect coming on.

3049. Colonel SABINE has shown that the months of May, June, July and August, may be classed together, so that I will not speak of each. Whilst they show the analogies they have between themselves, they also indicate the transitions to and from the other months. Let us consider September. From 7^h, through midnight on to 16^h, the needle stands nearly at the mean. From 16^h to 18^h, the upper or north end eastens through the effect of the early morning cold. That the eastening should be fully effected an hour sooner than before (3048.) is quite consistent with the principles, for the path of the sun and its diamagnetic region is far nearer to the station than before, being now about the equator. From 18^h to 22^h it sends the end westward, in conformity with all former observations, and then comes on the sun-swing from west to east, between 22^h and 24^h, and a hold at extreme east an hour longer. The shortness in time of this transit is, I think, a beautiful point. The sun is still north of St. Helena, but is now so much nearer that he passes through the *same angle* east and west, in respect to the place of observation, in less than half the time of the former sun effect in June (3041). After this the needle end travels west from 1^h to 6^h, following the sun as on other occasions; and then from 6^h to 9^h it moves a little east by the evening cold in the east, and remains near the mean position until the greater cold before sunrise (3005. 3011.) takes it more east between 16^h and 18^h of the coming day.

3050. In looking at the curves of variation (Plate II.), it will be seen that the curve for the next month, October, is remarkable for being like in general character, and yet far removed in place from that of September; and this effect appears due to the circumstance that the sun has now arrived at the latitude of St. Helena, or nearly so. According to my supposition, there has been a feeble night effect (3010.); and at midnight the needle is at the mean position and moving slowly westward, when the greater cold which precedes the sunrise coming into action on the east, counterbalances and arrests the western progress, and even draws the needle, as before, east a little for a couple of hours, till 18^h. Even the sun region is at 16^h in that quadrant (the south-east one), that if it could act on the needle it would combine with the cold in the next or north-east quadrant in setting it eastward. By 18^h both the preceding cold region and the following sun region are so far advanced in their respective quadrants that they combine to carry the needle end west as before, until 20^h, and then comes on the swing from west to east until 24^h. Why this begins sooner, lasts longer, and is above four times the extent of the September swing, appears to be that the sun region comes up upon the latitude of St. Helena, and so acts in respect of the magnetic meridian more powerfully, and also sooner and longer: also that because of the mean declination west it arrives at equidistant points from and passes over the magnetic meridian sooner; and also from the effect of an accumulative action added to it from former months (3053.).

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3051. At 1 o'clock the needle begins to turn from extreme east, *i. e.* sooner than in the former months, because the magnetic meridian is sooner passed, and follows the sun until 4^h, when it stops, and then the evening or night action due to cold appearing in the east, carries the needle back eastward till 10^h, and then as it advances in the quadrant lets the needle return back again (3004.) until between 12^h and 13^h, when the latter is in its mean position. The cold region then appears to draw it westward until 16^h, when its distance increasing it releases the needle, and lets it return east until 18 o'clock, when the latter is still west of its normal position, and then the sun region rising up, helped perhaps by the cold that immediately precedes it, which is probably now over or beyond the magnetic meridian, sets it toward the west prior to the sun-swing.

3052. In December and January the sun is south of the station. This makes no difference in the general character of the curve for these months; nor should it according to the hypothesis, except in this point, that though the sun is very near to St. Helena and has the cumulative effects of the preceding months (3050. 3053.) added to its own effect at the time, still it is in weaker parts of the quadrant, and whilst in the chief segment is almost up in the corner and near the place where the two neutral planes cross each other; hence its effect ought to be less, and so it is; for the sun-swing of November and February is larger than that of December and January. The sun-swing happens in December at the same time as for October, though in the latter month it crosses the magnetic meridian after, and in the present before mid-day: still there is only half an hour's difference from one to the other, and the observations are perhaps not close enough to allow one to separate its peculiar effect out of an interval of four hours. Besides, accumulative causes may interfere: the places of the December curve are altogether a little more west than those for October.

3053. The *cumulative* effect of preceding months is very important and well-shown at St. Helena (3050.). Thus, taking the September curve and comparing it with that for October or the following month, we have a great difference of a certain kind; then again comparing September with the month in which the sun is returning from the southern tropic instead of proceeding to it, and has arrived at the same position as it had in October, another striking difference appears. March is the nearest month for the second comparison. Up to 20^h its curve changes like the October curve, but the upper end of the needle is all the time about half a minute east of its place in October. At 20^h the needle in October begins to swing from west, and reaches extreme east at 24^h: in March it westens until 21^h, then returns and reaches extreme east at 1^h; so that the swing is an hour later, and during that time the end is from half a minute (of space) to a minute more west than in October. This difference I believe to be due to the cumulative effect of the months between October and March, during which time the heat has been diminishing in the northern hemisphere, and increasing in the south. Similar results in other months make it probable that

the effect of the atmosphere, though induced by the sun, lags behind the luminary, considered as in his astronomical position all the year round; and that therefore in advancing to and receding from a tropic, he seems to do less in the first instance and more in the second than is due to his place for the time.

3054. But where circumstances are apparently equal, a difference also arises. Thus from March to April in one direction, and from September to October in the other, might be expected to be alike, except for a little of the lagging effect (3053.), which would appear on both sides: nevertheless March and April are in SABINE's curves *between* September and October, and near together, whilst the other two are far apart. This effect I refer to the different conditions of the two hemispheres as regards heat (DOVE). From September to October the sun is passing from a hemisphere having a mean temperature in summer 17°·4 above that of the other hemisphere for its winter; but in March and April it is departing from a hemisphere having a mean summer temperature of only 10°·7 above that of the other hemisphere for its winter (2949.); and these respective differences must tend to separate September and October, and bring together March and April, as is seen to be the case by the curve charts, Plate II.

3055. I need not go further into the declination variation of St. Helena: the lines for the other months are subject to the observations already made. Colonel SABINE's important query of the cause of difference in direction for different months (3045.), appears to me at present to be answered for this station, as well as for the other stations, in very various latitudes where it makes its appearance (3016. 3022. 3039.).

3056. The *dip* at St. Helena is a daily variation very simple in character, being a maximum at 7^h and a minimum at 22^h and 23^h, with only one progression. It proceeds to its minimum therefore in the middle of the sun-swing, *i. e.* the upper end of the needle proceeds to west, and descends from 16^h to 19^h or 20^h, during which time therefore the dip is decreasing; then it returns east until it reaches the neutral position, the dip decreasing the while still more. The needle still continues to go east to complete the sun-swing, but now the dip increases; at 24^h or 1^h the needle returns (in declination) after the sun westward, but still with increasing dip; at 5^h or 6^h the westening has almost ceased, and an hour after the dip is at its maximum.

3057. So as the sun and its region pass over they diminish the dip by depressing the upper ends of the lines of force, and as they pass away the lines rise (2926. 2937.) and the dip increases. The ellipse or curve, therefore, which represents the motion of the upper end of the needle at St. Helena, as the sun comes up from the east, is above westward and downward, and back below to east; then rising to be repeated in the next twenty-four hours. This is the reverse direction to the representative ellipse for Hobarton, having like south dip in a greater degree. But that is in perfect consistency with the hypothesis; for as the region is located above in the air, it is above the angle which the dip makes with the horizon at St. Helena, and therefore ought to depress the line of force and lessen the dip. At Hobarton, the region being in the tropical parts, is within the angle formed by the line of dip with the horizon, and

therefore deflects the lines of force upwards and *increases* the dip, and so the portions of ellipse at the two places, which correspond in time and direction as to declination, have contrary variations of inclination.

3058. *Singapore**.—This is a very interesting station: being in longitude 103° 53′ E., it has only 1° 16′ N. latitude, and so is close to the equator. Its declination too is only 1° 40′ E., and its inclination 12° S. It is also near the line of weakest force round the earth. The magnetic equator of the needle is almost parallel to the earth's equator, and the quadrants (2929.) are distributed with great simplicity, the magnetic and astronomical meridian nearly coinciding. In our summer the sun passes through the east and west northern quadrants during the daytime; in our winter through the east and west southern quadrants; and in certain months through all four quadrants, following nearly the neutral line of the magnetic equator.

3059. Hence if the line of force were free, *i. e.* if it had no hold in the earth (2919.), we should expect from the hypothesis little or no change in the needle, especially in the months when the sun was over the magnetic equator; but because there is dip, and the lines of force which govern the needle are to the south tied up in the earth (2929.), whilst they are free to move in the air and space toward the north, so there is variation both of the declination and inclination in a perfectly consistent manner; and keeping this in mind, I think we shall have no difficulty in tracing the monthly results according to the hypothesis.

3060. In the first place, the curves of day variation are so like those of St. Helena, month for month, that the account given of them there will suffice for the present occasion (3048.). The sun-swing occurs at the same period, and the effect, dependent, as I suppose, on the character of the two hemispheres, is produced (3054. 2949.). There are however striking differences in the latter part of the sun turn, and also in the night hours, from 5^h to 14^h. The amount of variation appears small; but this is chiefly due to the circumstance that the horizontal plane on which we read it, almost coincides with the free needle, and so the correction before referred to (3009. note) necessary to give the true value of the variation is here very small.

3061. Considering *June* first, as at St. Helena, the upper needle end moves east as before until 19^h, under the influence of the morning cold, after which it stops and is sun-driven west until 22^h, when it swings downwards and beneath to east by 3^h; then follows the sun west until 7^h; it then stops and returns, creeping more and more east because of the coming cold (3065.). In July the needle eastens a little more before 19^h; westens until 23^h, and then eastens until 4^h. The sun-swing is thus thrown an hour later than in June, which I believe to be connected with the accumulation of heat over the land (3054.), combined with the lagging effect of the sun (3053.). In August the needle end eastens until 19^h; more than in July, and most of all the months: it then westens strongly before the sun until 23^h, after which the sun-swing

* See Tables, pp. 121, 122, and the curves of variation, Plate II. The data for Singapore are deduced from the recent very valuable labours of Captain Elliot.

comes on and continues until 5^h, as if the warm region were behind the sun, perhaps even 2^h. The time of the swing is much prolonged, and not unnaturally, as the place is at the equator and therefore under the sun. In September the eastening is less, the westening is less, and the sun-swing is less. April is like September, except that the latter shows the effect of the previously warmed hemisphere (3053.).

3062. Then there are four months in the year, November, December, January and February, when the sun is south of Singapore, and altogether during the day in the southern quadrants (3058.). As the sun comes on from 16^h or 17^h, the upper part of the line of force moves westward (the lower being fixed in the earth) until 19 or 20 o'clock. The sun is at this time in the south-east quadrant, and it might be expected perhaps that the motion of the north or upper end of the needle should be to the east if there were any change at all. But there are two or three reasons, from the hypothesis, why this should not be. For that effect there should first of all be no dip; and in the next place, if there were no dip, the sun is so nearly in the neutral line of the magnetic equator, that the deflection, if any, would have been very small. On the other hand, the lines of force have dip to the south, and being therefore held in the earth; that travelling of the sun along the neutral line, which in its coming up would have sent the whole line of force west, and so caused no variation of declination, can now only send the northern parts, as they rise out of the earth and are carried on with the general system of lines, west, and so cause that western travelling of the needle which does occur. Besides this, though the sun be south of that neutral line and also of Singapore, there is reason to suppose that the middle or resultant of the warm region is north even of both (3063.), which would aid the westening of the needle just described.

3063. For if we recall to mind Dove's results, they show that the northern hemisphere, as a whole, is warmer than the southern (2949.). Again, if we look at the meridian of Singapore, we shall find that there is far more continent on the north of it, to produce a higher temperature, than to the south; and even by the local tables of temperature below, we shall find that May, June, July and August are the hottest months for Singapore, and November, December, January and February the coldest; all tending to make us suppose that the warm region of the atmosphere is relatively north of the sun's place, and perhaps even of Singapore (3067.).

3064. At 20^h the sun-swing from west to east comes on, and continues until 2^h, after which the needle moves west, following the sun, until 10^h or 11^h when it is near the mean; it still goes on westening very slowly until 17^h, when the morning sun action takes it up and drives it more quickly west, until about 20^h, when the sun-swing east occurs. The curve in these months is very simple in its character; the night or cold effect appears to be but small, being indicated rather by a hesitation than by a distinct movement east.

3065. The easterly movement of the needle end in May, June, July and August, and the westerly movement in November, December, January and February, for the

same hours, up to 19 o'clock, is in striking contrast; and I have attributed the difference to the effect of a cold region coming on from the east during the former months (3061.), which is absent in the latter months. In reference to this point, we have again to consider that the warm region is on the north of the equator (3063.), and that as the sun moves north and south it also will move with it, but still keeping north of it. Hence the two cold regions, which come up to the meridian in higher latitudes (3006.) before the sun, will not be in the same relation to Singapore, for the one on the south will be nearer to it than the one on the north, or at all events more powerful. So when the sun is near and at the southern tropic, the warm region probably passes *over* Singapore, at which time, therefore, whilst it is the nearest, the most powerful and most direct in position, the cold regions will be *least* in force at the station, and also least favourably disposed by position. But when the sun is at the northern tropic, then the power of the warm region is diminished, both by distance and direction, and the southern cold region grows up into importance by increased strength and closer vicinity, and so produces the eastening before 19^h.

3066. A striking difference in the direction of the night curves, from 5^h to 14^h, at St. Helena and Singapore may be observed. At the former place the needle end tends first east and then west, whilst at the latter it moves first west and then east. The difference is, I believe, due to the appearance of night cold action at St. Helena to a greater extent than at Singapore. Singapore shows that action in June, July and August, as just described (3065.), but only in a weak degree and at a late hour. At St. Helena, which is in latitude 16° S., the cold effect should, for the reasons given above (3065.), appear in more power, and hence the eastening at 6^h and after; and that this is the cause is indicated also in a degree by the tables of temperature; for whilst at Singapore the difference between the maximum and minimum in the twenty-four hours is only from 3° to 4°, at St. Helena it is from 4°·5 to 7°, and four-fifths or even five-sixths of this depression occurs by 9 o'clock: so that four or five hours before that, there was in the east a cold region coming up and producing the eastening effect recorded in the curves.

3067. The *inclination* variation at Singapore is beautifully simple, and such as might be expected from the hypothesis; the sun or warm region, when passing the meridian, always being over the lines to depress them. It is alike in all the months, being greatest at night-time and least at midday; it is nearly the same from 8^h to 18^h; then as the sun comes up it decreases quickly until 23^h or 24^h, after which, as the sun passes away, it increases nearly as quickly until 7^h or 8^h. The amount of variation is greatest when the sun is over or to the south of Singapore. It is least in June and July, when he is near the northern tropic. In December and January, when he is near the southern tropic, it is considerably more than in June and July, which again seems to show that the warm region is chiefly north of the sun (3063.).

3068. The total force variation is simple, being a maximum from 9^h to 12^h, and a minimum at 22^h or 23^h, near noon. The greatest variation is in April and October,

or at the equinoxes, and the least in December and June, when the sun is at the tropics. The force is the least towards noon, when I suppose that the air above is in the worst condition of conduction, and would cause a magnet in it to show more power. But how that may affect the curves beneath on the surface of the earth, where they are compressed together, is doubtful, and the whole matter of intensity is too uncertain and has too many bearings for me to consider it usefully here.

3069. I hope soon to give further experimental data for the purpose of illustrating and testing the view of the physical cause of the magnetic variations which I have put forth, namely, those I expect to obtain by the differential balance, and others concerning the sensible influence of oxygen in causing, under different conditions, deflection of the lines of magnetic force.

Royal Institution,
November 16, 1850.

Cape of Good Hope.—Longitude 18° 30′ East. Latitude 33° 56′ South. Declination 29° 05′ West. Inclination 53° 15′ South.

Mean Diurnal variation of the Declination in each month of the years 1841 to 1846.

Increasing numbers denote a movement of the north or upper end of the magnet towards the East.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	4·11	5·43	5·50	5·04	4·64	4·29	3·96	4·16	4·43	4·36	4·27	4·13	3·98	3·79	3·56	3·32	3·09	2·67	2·01	1·15	0·37	0·36	1·39	2·93	3·28
February.....	5·51	7·48	8·21	7·86	7·06	6·11	5·74	5·83	5·90	5·82	5·74	5·69	5·78	5·73	5·55	5·50	5·38	5·27	4·90	3·36	1·26	0·00	0·82	2·96	4·33
March.....	5·34	6·74	7·29	6·93	6·17	5·48	5·32	5·33	5·42	5·39	5·28	5·40	5·34	5·52	5·59	5·54	5·52	5·39	4·95	3·22	1·04	0·02	1·26	3·44	4·66
April	4·07	5·00	4·76	4·21	3·75	3·53	3·42	3·39	3·44	3·45	3·51	3·56	3·53	3·98	3·96	4·07	4·17	4·32	4·15	3·29	1·32	0·00	0·39	0·96	3·30
May.....	1·83	2·49	2·81	2·92	2·50	2·15	2·17	2·31	2·33	2·30	2·45	2·41	2·64	2·83	2·87	3·10	2·24	3·36	3·80	3·91	2·31	0·68	0·00	0·62	2·42
June	0·74	1·27	1·87	1·87	1·36	1·05	1·11	1·19	1·24	1·34	1·49	1·63	1·74	2·00	2·04	2·25	2·22	2·28	2·59	3·21	2·38	0·86	0·00	0·10	1·58
July.....	0·60	1·18	1·96	2·09	1·54	1·06	1·06	1·09	1·19	1·31	1·46	1·74	2·03	2·22	2·23	2·32	2·46	2·61	3·08	3·56	2·74	1·35	0·28	0·02	1·71
August	0·62	1·52	2·50	3·23	2·93	2·22	2·27	2·34	2·46	2·56	2·49	2·64	2·77	2·91	3·01	3·32	3·45	3·63	4·35	4·98	3·65	1·74	0·36	0·00	2·71
September ...	1·58	2·64	3·22	3·27	2·94	2·57	2·64	2·73	2·75	2·76	2·82	2·84	2·91	3·05	3·06	3·19	3·22	3·36	4·33	4·10	2·43	0·84	0·00	0·49	2·65
October	4·90	5·81	5·96	5·23	4·29	3·69	3·84	4·05	4·09	4·17	4·18	4·16	4·16	4·15	3·96	3·79	3·63	3·40	2·78	1·37	0·14	0·00	1·27	3·18	3·59
November ...	5·19	6·15	6·36	5·98	5·43	4·98	5·08	5·26	5·32	5·39	5·37	5·37	5·34	5·13	4·84	4·55	4·15	3·41	2·05	0·68	0·00	0·57	2·19	3·88	4·28
December ...	4·64	5·48	5·51	5·08	4·47	4·41	4·24	4·42	4·54	4·60	4·66	4·67	4·62	4·36	4·07	3·74	3·38	2·63	1·42	0·39	0·04	0·55	2·05	3·56	3·62

Cape of Good Hope.—Mean Diurnal variation of the inclination in each month of the year, from April 1841 to June 1846.

Increasing numbers denote increasing inclination. Inclination 53° 15′ South.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	0·03	0·00	0·34	0·56	0·72	1·00	1·25	1·35	1·46	1·51	1·50	1·41	1·37	1·40	1·30	1·22	1·18	1·10	0·94	0·99	0·97	0·92	0·66	0·23	0·98
February.....	0·13	0·00	0·44	1·05	1·55	1·91	2·01	2·14	2·14	2·09	2·94	1·94	1·70	1·63	1·65	1·56	1·63	1·70	1·66	1·94	2·26	2·08	1·45	0·66	1·56
March.....	0·11	0·00	0·46	1·05	1·45	1·86	2·09	2·21	2·16	2·02	1·94	1·79	1·79	1·46	1·35	1·46	1·45	1·50	1·51	1·69	1·81	1·66	1·90	0·41	1·38
April	0·00	0·49	1·05	1·55	1·76	1·89	2·16	2·21	2·11	2·06	1·88	1·65	1·45	1·18	1·18	1·07	1·25	1·12	1·10	1·10	1·48	1·53	0·92	0·33	1·35
May	0·00	0·38	0·70	0·86	1·08	1·16	1·27	1·31	1·49	1·59	1·39	1·32	1·16	0·89	0·83	0·89	0·76	0·68	0·30	0·15	0·53	0·66	0·56	0·12	0·84
June	0·41	0·53	0·58	0·76	0·64	0·79	0·96	1·22	1·34	1·40	1·29	1·22	1·04	0·96	0·89	0·81	0·73	0·78	0·36	0·00	0·07	0·38	0·36	0·43	0·75
July	0·62	0·64	0·59	0·64	0·77	0·87	1·18	1·20	1·46	1·43	1·43	1·21	1·07	0·95	0·77	0·87	0·67	0·60	0·28	0·00	0·18	0·51	0·64	0·56	0·80
August	0·12	0·38	0·76	0·99	1·16	1·27	1·34	1·60	1·55	1·52	1·45	1·30	1·16	1·04	0·84	0·83	0·63	0·68	0·27	0·00	0·13	0·33	0·43	0·30	0·84
September ...	0·00	0·23	0·66	1·09	1·40	1·65	1·78	1·68	1·75	1·75	1·40	1·27	0·91	0·97	0·56	0·81	0·51	0·73	0·18	0·31	0·07	0·35	0·43	0·12	0·84
October	0·00	0·08	0·53	1·17	1·75	1·98	1·98	1·89	1·88	1·75	1·60	1·50	1·28	1·23	1·20	1·10	1·09	1·07	1·07	1·09	1·04	0·77	0·36	0·05	1·14
November ...	0·14	0·00	0·29	0·64	1·12	1·53	1·41	1·46	1·48	1·33	1·25	1·08	0·99	0·94	0·90	0·87	0·87	0·94	0·90	0·62	0·46	0·26	0·06	0·00	0·81
December ...	0·13	0·30	0·87	1·22	1·40	1·53	1·78	2·01	2·04	1·81	1·70	1·57	1·50	1·48	1·47	1·50	1·50	1·40	1·05	0·81	0·48	0·15	0·02	0·00	1·15
Hourly means	0·14	0·25	0·61	0·96	1·23	1·45	1·60	1·69	1·74	1·69	1·49	1·44	1·28	1·18	1·09	1·08	1·02	1·02	0·79	0·72	0·79	0·80	0·54	0·27	1·04

Cape of Good Hope.—Mean Diurnal variation of the Intensity in each month of the year, from April 1841 to June 1846.

Increasing numbers denote increasing intensity.

The numbers express the changes in parts of the whole Force. Approximate Total Intensity 7·5.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	000	003	018	031	041	047	048	039	036	038	040	044	045	047	049	050	052	061	071	079	078	056	028	005	042
February.....	000	000	020	047	069	083	076	072	068	069	071	071	074	075	078	076	077	080	092	115	127	105	062	026	068
March.....	000	007	027	052	070	079	074	069	064	064	067	066	070	068	066	068	068	068	081	103	119	094	047	011	063
April	000	017	040	058	070	071	068	065	060	059	059	060	060	059	060	063	061	060	065	083	102	093	059	021	059
May	003	000	008	019	036	038	035	028	025	023	021	021	022	020	020	019	019	018	013	026	056	063	050	020	025
June	008	000	003	015	029	030	026	021	017	014	017	010	010	007	009	007	010	008	004	003	030	041	039	017	015
July.....	009	004	005	016	032	033	026	023	018	013	010	007	007	007	008	009	008	007	000	005	027	043	041	023	016
August	028	013	007	010	028	035	029	024	019	016	017	016	016	016	017	013	013	009	000	009	044	061	064	044	023
September ...	007	000	005	015	023	028	021	017	013	012	013	012	019	015	020	014	019	008	005	018	051	057	050	023	019
October	000	009	033	057	070	064	053	047	045	047	047	049	051	055	056	056	056	060	073	088	084	060	025	005	050
November ...	000	005	021	038	049	057	048	044	043	044	044	047	050	053	056	057	052	074	090	096	082	054	022	007	047
December ...	000	003	015	029	037	035	034	030	027	026	028	031	035	036	038	042	047	060	074	076	066	042	013	000	034
Hourly means	005	005	017	032	046	050	045	040	036	035	036	036	038	038	040	040	040	043	047	058	072	064	042	017	461

Cape of Good Hope.—Mean Temperature of the Air from April 1841 to June 1846 inclusive. FAHRENHEIT's scale.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	73°16	73°30	73°03	72°43	71°52	70°30	67°94	66°11	65°45	65°01	64°51	64°10	63°77	63°54	63°32	63°06	62°85	63°18	65°20	67°24	68°78	70°05	71°46	72°59	67°58
February.....	74°04	74°07	73°63	72°85	71°74	70°36	68°20	66°69	66°13	65°75	65°34	64°93	64°54	64°23	64°00	63°60	63°41	63°12	64°46	66°33	67°94	69°72	71°62	73°10	67°91
March.....	71°74	72°40	72°19	71°40	69°96	68°07	65°98	64°98	64°38	63°69	63°20	62°85	62°37	62°06	61°69	61°44	61°15	60°97	61°31	63°03	65°39	67°48	69°50	71°00	65°76
April	68°39	68°94	68°90	68°06	66°56	64°22	62°69	62°13	61°54	60°98	60°46	59°87	59°53	59°27	59°00	58°80	58°40	58°28	58°17	59°49	61°82	64°14	65°95	67°35	62°62
May.....	62°32	62°55	62°43	61°74	60°49	58°99	58°06	57°41	56°81	56°39	55°85	55°48	55°37	55°21	55°05	54°81	54°59	54°32	54°04	54°44	56°42	58°48	60°09	61°29	57°61
June	58°45	58°79	58°78	58°32	57°01	55°58	54°79	54°25	53°71	53°25	52°77	52°32	52°16	51°86	51°69	51°53	51°21	50°95	50°80	50°93	52°20	54°42	56°17	57°42	54°14
July	59°15	59°66	59°65	59°21	57°77	56°13	55°15	54°47	53°83	53°34	52°86	52°37	52°06	51°72	51°42	51°19	50°96	50°83	50°51	50°88	52°67	54°94	56°87	58°28	54°41
August	58°86	59°23	59°07	58°61	57°61	55°91	55°01	54°35	53°91	53°60	53°17	52°91	52°71	52°31	52°07	51°87	51°54	51°19	51°15	51°88	53°19	55°57	57°05	58°30	54°63
September ...	61°60	61°79	61°68	60°87	59°65	58°02	56°78	56°09	55°62	55°22	54°58	54°47	54°36	53°95	53°64	53°31	53°10	53°20	53°13	54°94	56°90	58°61	59°94	60°94	56°77
October	65°48	65°71	65°46	64°66	63°38	61°56	59°51	58°68	58°05	57°51	57°14	56°74	56°70	56°33	56°11	55°88	55°64	55°63	57°14	59°08	61°00	62°75	64°07	65°04	59°97
November ...	68°00	68°03	67°63	66°98	66°19	64°82	62°49	61°12	60°38	59°99	59°52	59°12	58°82	58°43	58°00	57°69	57°48	58°14	60°55	62°50	63°96	65°27	66°50	67°50	62°46
December ...	71°02	71°23	70°84	70°21	69°63	68°23	65°69	63°94	63°19	62°64	62°07	61°59	61°18	60°82	60°49	60°17	59°91	60°83	63°41	65°80	67°17	68°42	69°62	70°42	65°35

St. Helena.—Longitude 5° 40′ West. Latitude 15° 56′ South. Declination 23° 36′ West. Inclination 21° 40′ South.

Mean Diurnal variation of the Declination for the years 1841 to 1845 inclusive.

Increasing numbers denote increasing eastening of the north or upper end of the needle. Mean Declination 23° 36′·6 West.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	3·72	3·19	2·41	2·03	2·09	1·84	1·92	2·41	2·80	2·90	2·86	2·81	2·63	2·43	2·23	2·01	1·73	1·68	1·50	0·59	0·00	0·57	1·75	3·15	2·13
February.....	4·53	4·51	4·11	3·39	2·80	2·55	2·61	3·02	3·21	3·35	3·48	3·52	3·42	3·22	3·12	2·98	2·83	2·75	2·64	1·14	0·00	0·31	1·52	3·34	2·85
March.....	3·76	4·11	3·48	2·57	2·15	2·20	2·48	2·64	2·69	2·68	2·85	2·84	2·80	2·77	2·68	2·70	2·69	2·70	2·96	1·90	0·26	0·00	1·13	2·72	2·49
April	3·28	2·48	1·65	1·27	1·03	1·01	1·23	1·50	1·56	1·60	1·71	1·81	1·96	1·92	1·92	2·00	2·16	2·22	2·47	3·15	0·62	0·00	0·82	2·57	1·70
May	0·71	0·44	0·57	0·71	0·55	0·21	0·25	0·48	0·56	0·72	0·78	0·90	1·02	1·09	1·11	1·18	1·32	1·57	2·04	2·58	1·50	0·32	0·00	0·49	0·88
June	0·71	0·73	0·88	0·94	0·44	0·00	0·10	0·39	0·56	0·73	0·90	1·06	1·17	1·22	1·25	1·29	1·40	1·66	2·16	3·31	2·69	1·39	0·75	0·69	1·10
July	0·82	0·71	0·78	0·84	0·48	0·02	0·00	0·22	0·46	0·64	0·84	0·98	1·08	1·14	1·14	1·24	1·31	1·46	2·02	3·11	2·58	1·31	0·63	0·67	1·02
August	0·11	0·00	0·40	0·86	0·82	0·42	0·25	0·52	0·68	0·78	0·88	1·02	1·02	1·02	1·04	1·18	1·27	1·61	2·37	3·43	2·52	1·19	0·36	0·05	0·99
September ...	0·89	0·85	0·65	0·44	0·35	0·28	0·28	0·53	0·62	0·67	0·79	0·78	0·75	0·64	0·61	0·65	0·70	0·95	2·12	1·89	0·85	0·17	0·00	0·43	0·70
October	4·41	4·35	3·43	2·06	1·23	1·32	1·80	2·04	2·21	2·34	2·45	2·43	2·23	2·00	1·92	1·81	1·72	1·74	1·99	0·49	0·00	0·72	2·08	3·61	2·10
November ...	3·97	3·82	3·31	2·52	1·85	1·85	2·29	2·77	2·99	3·13	3·21	3·13	2·96	2·68	2·46	2·22	1·97	1·80	1·53	0·21	0·00	1·03	2·22	3·41	2·39
December ...	3·65	3·48	2·70	1·94	1·66	1·85	2·15	2·58	2·93	3·12	3·20	3·13	2·89	2·64	2·40	2·17	1·93	1·73	1·38	0·32	0·00	0·86	2·09	3·32	2·25

St. Helena.—Mean Diurnal variation of the Inclination in each month, from January 1841 to December 1845.

Increasing numbers denote increasing inclination. Mean Inclination 21° 40′ South.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	0·14	0·46	1·07	1·49	2·18	2·53	2·77	2·91	2·87	2·83	2·77	2·63	2·40	2·23	1·99	1·85	1·80	1·77	1·65	1·37	0·88	0·53	0·00	0·02	1·71
February.....	0·23	0·61	1·33	2·00	2·39	2·78	3·01	3·15	3·12	2·98	2·86	2·73	2·61	2·46	2·44	2·21	2·15	2·00	2·04	1·82	1·40	0·94	0·10	0·00	1·97
March.....	0·11	0·56	1·33	1·86	2·21	2·47	2·80	2·97	2·99	2·89	2·89	2·67	2·46	2·37	2·26	2·12	1·99	2·01	1·84	1·53	1·06	0·43	0·00	0·10	1·83
April	0·45	0·89	1·54	2·14	2·53	2·83	3·05	3·17	3·26	2·88	2·97	2·63	2·41	2·18	2·15	2·08	1·88	1·77	1·47	1·30	0·94	0·43	0·27	0·00	1·88
May.....	0·20	0·74	1·16	1·62	1·90	2·10	2·22	2·36	2·28	2·21	2·12	1·99	1·77	1·69	1·56	1·33	1·21	1·16	1·18	1·09	0·81	0·36	0·00	0·03	1·38
June	0·18	0·56	1·04	1·58	1·65	1·91	2·21	2·26	2·24	2·12	2·02	1·98	2·06	1·77	1·68	1·54	1·46	1·36	1·22	0·98	0·80	0·43	0·09	0·00	1·38
July	0·30	0·60	1·06	1·44	1·82	2·01	2·42	2·47	2·40	2·35	2·21	2·04	1·80	1·58	1·52	1·30	1·25	1·08	1·00	0·84	0·53	0·27	0·00	0·03	1·35
August	0·25	0·72	1·21	1·61	1·94	2·16	2·35	2·40	2·39	2·19	2·12	1·98	1·80	1·69	1·58	1·40	1·33	1·25	1·13	1·07	0·79	0·54	0·19	0·00	1·49
September ...	0·18	0·70	1·29	1·72	2·02	2·19	2·40	2·40	2·32	2·13	2·01	1·99	1·80	1·68	1·47	1·50	1·51	1·44	1·40	1·27	0·92	0·60	0·36	0·00	1·47
October	0·24	0·74	1·36	1·90	2·34	2·56	2·55	2·88	2·65	2·56	2·46	2·28	2·09	2·04	1·89	1·80	1·70	1·69	1·63	1·31	0·88	0·37	0·00	0·02	1·66
November ...	0·08	0·27	0·74	1·19	1·63	2·00	2·35	2·45	2·38	2·30	2·18	2·07	1·96	1·83	1·71	1·59	1·66	1·48	1·35	0·92	0·55	0·23	0·00	0·10	1·38
December ...	0·26	0·73	1·06	1·59	2·08	2·41	2·69	2·78	2·51	2·45	2·39	2·15	2·01	1·80	1·72	1·56	1·48	1·38	1·26	0·85	0·40	0·10	0·00	0·07	1·49
Hourly means	0·22	0·63	1·18	1·68	2·06	2·33	2·57	2·68	2·63	2·49	2·42	2·26	2·10	1·94	1·83	1·69	1·62	1·53	1·43	1·20	0·83	0·44	0·08	0·03	1·58

St. Helena.—Mean Diurnal variation of the Total Intensity in each month, from January 1841 to December 1845.

Increasing numbers denote increasing intensity.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	130	129	116	098	081	063	046	027	016	004	000	001	001	008	015	015	019	019	024	040	055	080	109	124	051
February.....	117	109	092	077	063	050	029	014	007	001	002	003	004	002	000	002	002	003	009	023	046	070	095	114	039
March	153	147	124	096	070	055	032	020	010	000	006	004	001	016	014	018	018	021	026	040	068	102	132	149	055
April	162	150	122	088	068	042	021	010	005	001	004	000	007	014	015	016	025	024	024	031	054	090	102	150	051
May.....	163	142	115	087	065	049	036	023	016	011	004	000	008	008	011	018	019	019	025	034	048	095	132	159	054
June	141	128	101	064	063	047	028	015	006	004	001	000	002	003	004	004	004	009	013	022	042	075	110	137	043
July.....	126	117	095	073	051	042	027	015	011	002	002	000	003	005	006	011	015	018	019	024	038	068	097	116	041
August	139	126	103	077	053	038	026	013	004	001	000	000	002	005	009	015	015	016	016	018	037	068	103	131	039
September ...	143	131	105	077	056	037	026	013	004	000	003	007	011	014	018	024	022	024	023	022	038	069	101	134	046
October	135	123	105	088	070	051	030	015	007	001	000	005	011	013	019	020	019	020	017	032	058	093	123	135	050
November ...	112	111	101	090	076	055	029	018	007	000	002	009	011	011	016	017	017	017	026	048	071	087	105	112	048
December ...	116	110	105	089	071	051	027	011	004	000	000	003	003	006	008	010	011	012	024	046	064	086	107	117	045
Hourly means	136	127	107	084	066	048	030	016	008	002	002	003	006	009	011	014	015	017	021	032	052	082	110	132	047

St. Helena.—Mean Temperature of the Air from 1841 to 1845 inclusive.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	67·68	68·05	67·93	67·79	67·30	66·04	64·58	63·39	62·93	62·62	62·42	62·27	62·06	61·88	61·66	61·60	61·49	61·39	61·37	61·84	62·79	64·09	65·38	66·55	63·98
February.....	69·14	69·61	69·85	69·59	68·95	67·89	66·59	65·43	64·91	64·66	64·46	64·32	64·13	63·96	63·78	63·59	63·51	63·44	63·42	63·62	64·43	65·72	67·08	68·24	65·87
March	69·13	69·57	69·89	69·71	69·10	68·10	66·86	65·84	65·47	65·15	65·00	64·83	64·65	64·50	64·31	64·17	64·15	64·03	64·05	64·29	65·08	66·39	67·35	68·38	66·24
April	68·54	68·89	68·98	68·64	67·99	66·98	65·84	65·15	64·84	64·61	64·45	64·29	64 11	64·02	63·88	63·77	63·66	63·51	63·49	63·69	64·50	65·70	66·74	67·86	65·60
May	65·76	66·01	66·09	65·84	65·17	64·11	63·56	63·32	62·73	62·13	62·03	61·88	61·67	61·57	61·40	61·24	61·19	61·19	61·04	61·06	62·01	63·22	64·11	65·22	63·05
June	62·40	62·76	62·73	62·39	61·83	60·98	60·14	59·68	59·49	59·34	59·20	59·11	59·00	58·86	58·74	58·61	58·56	58·53	58·47	58·52	59·13	60·16	60·98	61·80	60·07
July.....	60·37	60·83	60·77	60·51	59·87	58·98	58·14	57·70	57·48	57·25	57·13	56·91	56·81	56·72	56·60	56·51	56·43	56·36	56 31	56·38	57·07	58·09	58·90	59·69	57·99
August	59 68	59·99	60·12	59·79	59·11	58·11	57·23	56·83	56·60	56·45	56·32	56·20	56·10	55·98	55·76	55·68	55·53	55·50	55·39	55·56	56·20	57·22	58·07	58·96	57·17
September ...	59·89	60·26	60·18	59·77	59·11	58·03	57·05	56·56	56·35	56·21	56·04	55·91	55·82	55·67	55·51	55·37	55·29	55·21	55·21	55·44	56·12	57·18	58·21	59·14	57·07
October	61·50	61·98	61·91	61·31	60·46	59·31	58·18	57·57	57·64	57·12	56·99	56·84	56·64	56·48	56·30	56·18	56·11	56·01	56·06	56·50	57·38	58·61	59·71	60·73	58·23
November ...	63·44	63 88	63·97	63·52	62·63	61·32	59·94	59·11	58·76	58·57	58·41	58·24	58·08	57·90	57·71	57·62	57·55	57·43	57·53	58·03	58·94	60·20	61·35	62 35	59·84
December ...	65·19	65·81	65·87	65·72	64·88	63 62	62·17	61·10	60·70	60·46	60·27	60·12	59·95	59·75	59·57	59·47	59·34	59·31	59·39	59·77	60·69	61·97	63·03	64·19	61·77

Singapore.—Latitude 1° 16′ North. Longitude 103° 53′ East. Declination 1° 40′ East (Approx.). Inclination 12° South (Approx.).

Mean Hourly oscillation of the Magnetic Declination for each month of the years 1843, 1844 and 1845.

Increasing numbers denote a movement of the north or upper end of the magnet towards the East.

Mean time ...	Noon. 0½h.	1½h.	2½h.	3½h.	4½h.	5½h.	6½h.	7½h.	8½h.	9½h.	10½h.	11½h.	Midn. 12½h.	13½h.	14½h.	15½h.	16½h.	17½h.	18½h.	19½h.	20½h.	21½h.	22½h.	23½h.	Daily means.
January	2·04	2·52	2·79	2·72	2·52	2·24	2·11	2·18	2·04	1·97	1·84	1·70	1·63	1·63	1·50	1·43	1·29	1·02	0·61	0·00	0·00	0·41	0·82	1·22	1·59
February.....	2·31	2·92	3·13	3·06	2·79	2·52	2·31	2·31	2·18	2·04	1·90	1·90	1·97	1·90	1·90	1·90	1·84	1·70	1·29	0·54	0·00	0·00	0·34	1·43	1·84
March.....	1·29	1·43	1·63	1·77	1·63	1·43	1·29	1·09	0·95	0·68	0·82	0·82	0·88	0·88	0·88	0·82	0·82	0·82	0·82	0·48	0·00	0·07	0·54	1·02	0·96
April	0·34	0·61	0·75	1·02	1·16	1·16	0·95	0·82	0·61	0·54	0·61	0·68	0·82	0·95	0·95	0·95	0·88	0·82	1·16	0·95	0·34	0·00	0·20	0·41	0·70
May.....	0·07	0·48	0·82	1·16	1·36	0·95	1·02	0·88	0·75	0·68	0·75	0·82	1·09	1·16	1·29	1·36	1·36	1·43	2·11	2·24	1·43	0·68	0·27	0·00	0·75
June	0·20	0·41	0·54	0·61	0·54	0·34	0·14	0·00	0·00	0·00	0·07	0·20	0·41	0·54	0·61	0·68	0·68	0·82	1·36	1·56	0·82	0·41	0·00	0·14	0·46
July.....	0·07	0·41	0·61	0·88	1·02	0·88	0·48	0·34	0·27	0·20	0·27	0·34	0·54	0·68	0·82	0·75	0·82	1·16	1·63	1·97	1·29	0·54	0·14	0·00	0·67
August	0·20	0·68	1·02	1·56	1·63	1·84	1·43	1·29	1·09	1·02	1·02	1·16	1·22	1·36	1·43	1·50	1·50	1·70	2·52	2·79	1·77	0·75	0·14	0·00	1·27
September ...	0·48	0·88	1·36	1·63	1·63	1·56	1·50	1·29	1·16	1·09	1·02	1·09	1·16	1·22	1·29	1·29	1·36	1·43	1·97	1·77	0·75	0·20	0·00	0·20	1·14
October	1·90	2·31	2·31	2·18	1·97	1·77	1·77	1·63	1·50	1·36	1·29	1·29	1·43	1·36	1·36	1·29	1·22	1·09	1·16	0·54	0·14	0·00	0·27	1·02	1·33
November ...	2·45	2·92	2·99	2·86	2·45	2·11	1·97	1·84	1·70	1·56	1·36	1·36	1·43	1·43	1·36	1·29	1·16	1·02	0·48	0·00	0·00	0·27	0·82	1·63	1·51
December ...	2·52	2·99	2·99	2·99	2·86	2·45	2·18	2·04	1·97	1·84	1·70	1·63	1·56	1·56	1·56	1·50	1·43	1·16	0·61	0·00	0·00	0·41	1·02	1·77	1·70

Singapore.—Mean Diurnal variation of the Inclination in the several months during the years 1843, 1844 and 1845.

Increasing numbers denote increasing inclination. Approximate inclination 12° South.

Mean time ...	Noon. 0½h.	1½h.	2½h.	3½h.	4½h.	5½h.	6½h.	7½h.	8½h.	9½h.	10½h.	11½h.	Midn. 12½h.	13½h.	14½h.	15½h.	16½h.	17½h.	18½h.	19½h.	20½h.	21½h.	22½h.	23½h.	Daily means.
January	0·00	0·43	0·98	1·28	1·90	2·07	2·38	2·57	2·62	2·71	2·76	2·76	2·66	2·71	2·71	2·72	2·72	2·72	2·73	2·52	1·97	1·09	0·32	0·02	1·97
February.....	0·04	0·64	1·24	1·75	2·00	2·21	2·56	2·82	2·94	3·02	3·10	3·07	3·08	3·03	2·98	2·99	2·97	2·97	3·03	2·88	2·35	1·21	0·40	0·00	2·22
March.....	0·06	0·29	0·75	1·36	1·75	1·88	2·22	2·55	2·65	2·70	2·74	2·72	2·72	2·67	2·71	2·72	2·72	2·75	2·75	2·54	1·84	0·75	0·11	0·00	1·91
April	0·28	0·82	1·54	2·09	2·47	2·71	3·04	3·00	3·27	3·36	3·41	3·49	3·43	3·40	3·33	3·29	3·29	3·27	3·15	2·92	2·18	1·15	0·28	0·00	2·46
May.....	0·00	0·32	0·80	1·17	1·62	1·96	2·29	2·34	2·42	2·43	2·42	2·20	2·38	2·40	2·42	2·46	2·52	2·51	2·25	1·87	1·25	0·49	0·03	0·00	1·69
June	0·04	0·20	0·57	0·98	1·44	1·50	2·20	2·25	2·19	2·16	2·10	2·07	2·15	2·21	2·15	2·20	2·21	2·29	2·02	1·71	1·25	0·69	0·22	0·00	1·53
July.....	0·00	0·15	0·45	0·89	1·34	1·76	2·10	2·16	2·19	2·20	2·20	2·07	2·18	2·19	2·19	2·21	2·21	2·27	2·02	1·74	1·28	0·69	0·27	0·05	1·53
August	0·12	0·34	0·69	1·01	1·35	1·68	1·99	2·32	2·21	2·27	2·26	2·28	2·26	2·20	2·18	2·22	2·21	2·22	1·93	1·68	1·30	0·62	0·14	0·00	1·56
September ...	0·41	1·00	1·60	1·94	2·11	2·32	2·58	2·69	2·78	2·82	2·85	2·84	2·85	2·79	2·74	2·75	2·75	2·79	2·66	2·39	1·66	0·79	0·15	0·00	2·09
October	0·38	1·17	1·94	2·38	2·48	2·59	2·86	3·07	3·23	3·29	3·34	3·23	3·33	3·23	3·22	3·20	3·24	3·20	3·25	2·96	2·18	1·14	0·21	0·00	2·46
November ...	0·16	0·63	1·37	1·96	2·32	2·68	2·88	2·87	3·02	3·08	3·07	3·05	3·06	3·03	3·02	2·95	3·01	3·00	3·15	2·80	2·01	1·04	0·17	0·00	2·26
December ...	0·09	0·54	1·13	1·62	1·92	2·26	2·53	2·66	2·85	2·86	2·85	2·86	2·76	2·76	2·72	2·69	2·65	2·69	2·44	2·38	1·81	1·08	0·34	0·00	2·02
Hourly means	0·13	0·54	1·09	1·54	1·89	2·14	2·47	2·61	2·70	2·74	2·76	2·72	2·74	2·72	2·70	2·70	2·71	2·72	2·62	2·37	1·76	0·89	0·22	0·01	1·98

Singapore.—Mean Diurnal variation of the Total Intensity in the several months during the years 1843, 1844, 1845.

Increasing numbers indicate increase of total intensity.

The numbers express the changes in parts of the whole force. Approximate total intensity 8·21.

Mean time ...	Noon. 0½h.	1½h.	2½h.	3½h.	4½h.	5½h.	6½h.	7½h.	8½h.	9½h.	10½h.	11½h.	Midn. 12½h.	13½h.	14½h.	15½h.	16½h.	17½h.	18½h.	19½h.	20½h.	21½h.	22½h.	23½h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	086	066	047	030	028	021	015	009	009	003	002	000	007	002	008	007	010	012	022	033	054	074	099	100	031
February.....	099	080	061	042	027	024	013	008	004	000	000	002	000	001	005	005	009	011	014	025	049	082	103	110	032
March	114	085	055	035	026	020	013	007	003	001	000	002	005	008	007	009	011	012	012	027	057	087	119	122	035
April	122	094	065	040	029	020	016	011	005	003	005	002	000	004	009	011	013	015	020	043	076	110	139	137	041
May.....	104	081	060	036	020	013	014	011	010	006	006	000	004	006	006	006	008	012	025	044	073	097	114	118	036
June	096	075	051	026	011	042	004	004	001	000	000	000	001	001	003	004	004	008	020	038	062	085	102	105	031
July	100	081	056	033	019	013	007	007	004	002	000	002	002	004	006	004	010	015	026	044	070	091	105	110	034
August	101	081	055	033	016	009	010	005	006	000	002	002	004	010	011	011	016	018	028	046	077	096	115	114	036
September ...	093	065	037	029	018	009	009	008	002	001	000	003	003	008	014	018	019	017	023	045	079	104	117	115	035
October	102	073	050	036	029	024	013	007	003	000	000	001	006	011	011	016	019	017	020	037	070	101	117	121	037
November ...	080	063	044	030	021	015	009	003	001	000	001	000	002	006	007	013	012	013	017	034	059	082	098	095	029
December ...	077	061	044	031	026	021	012	004	000	000	001	002	003	006	009	013	014	014	019	035	056	078	095	091	030
Hourly means	098	075	052	033	022	019	011	007	004	002	002	001	003	006	008	010	012	014	021	038	065	091	110	112	034

Singapore.—Mean Temperature of the Air observed on the Standard Thermometer inside the Observatory, during the years 1841, 1842 and 1843.

Mean time ...	Noon. 0½h.	1½h.	2½h.	3½h.	4½h.	5½h.	6½h.	7½h.	8½h.	9½h.	10½h.	11½h.	Midn. 12½h.	13½h.	14½h.	15½h.	16½h.	17½h.	18½h.	19½h.	20½h.	21½h.	22½h.	23½h.	Daily means.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	79·7	79·5	80·0	79·5	79·7	79·1	78·0	78·4	78·5	78·0	78·1	77·5	77·9	77·3	77·6	78·9	77·4	76·5	77·0	78·3	77·3	77·4	78·6	78·8	78·2
February.....	80·7	81·6	81·2	82·1	81·2	82·1	80·2	80·6	79·7	80·2	79·2	79·6	78·6	79·0	78·3	78·6	78·2	78·2	77·7	78·2	78·0	79·4	79·6	81·8	79·8
March	81·4	82·1	81·7	82·3	81·6	82·0	80·9	81·5	80·5	81·2	80·1	81·0	79·9	80·6	79·4	80·3	79·1	79·9	78·7	79·8	79·4	80·6	80·6	81·5	80·7
April	81·8	81·8	82·1	81·8	81·9	81·6	81·4	81·2	81·0	80·9	80·7	80·2	80·3	80·3	79·9	80·0	79·5	79·6	79·2	79·8	79·9	80·6	81·1	81·4	80·8
May.....	82·5	.....	82·7	.....	82·5	.....	82·1	.....	81·8	.....	81·4	.....	80·9	.....	80·5	.....	80·3	.....	79·9	.....	80·9	.....	81·8	.....	81·4
June	82·5	82·9	82·7	83·1	82·5	82·7	82·2	82·0	81·7	81·6	81·4	81·4	81·2	81·2	80·7	80·7	80·3	80·2	80·1	80·4	81·0	81·7	81·8	82·6	81·6
July.....	82·4	82·0	82·8	83·1	82·7	82·7	82·2	82·1	81·8	81·9	81·5	81·5	81·1	81·2	80·7	80·9	80·3	80·6	80·8	80·8	80·8	81·9	81·9	82·6	81·7
August	81·7	81·9	81·9	81·9	81·8	81·8	81·4	81·3	81·0	81·2	80·8	80·8	80·4	80·3	80·1	80·1	79·8	79·8	79·5	79·8	80·2	80·8	81·2	81·6	80·9
September ...	82·1	82·6	82·4	82·3	82·2	82·1	81·7	81·6	81·5	81·2	81·0	80·8	80·5	80·3	80·1	80·0	79·7	79·7	79·4	79·4	80·3	80·9	81·4	81·8	81·0
October	81·5	81·3	81·7	81·4	81·7	81·2	81·2	80·6	80·7	80·2	80·1	79·8	79·6	79·8	79·4	79·3	79·0	79·3	78·7	79·2	79·5	80·0	80·7	80·9	80·3
November ...	81·1	81·0	81·3	80·8	81·0	80·6	80·4	80·1	80·1	79·7	79·7	79·6	79·3	79·1	78·9	78·7	78·6	78·5	78·4	78·5	79·2	79·6	80·2	80·5	79·8
December ...	81·0	81·3	81·3	81·3	80·9	80·8	80·2	80·0	79·6	79·4	79·2	79·2	79·0	79·0	78·6	78·4	78·1	78·1	77·9	78·2	78·7	79·5	80·1	80·7	79·6
Hourly means	81·5	81·7	81·8	81·8	81·6	81·5	81·1	80·9	80·7	80·5	80·3	80·1	79·9	79·8	79·5	79·4	79·2	79·1	78·9	79·1	79·6	80·2	80·7	81·3	80·4

V. *On Periodical Laws discoverable in the mean effects of the larger Magnetic Disturbances.* By Lieut.-Colonel Edward Sabine, *R.A., Treas. & V.P.R.S.*

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In the preface to the first part of the first volume of the "Observations on days of unusual Magnetic Disturbance at the British Colonial Observatories," published in 1843, and in the introductory comments prefixed to the first volume of the "Observations at the Toronto Observatory," published in 1845, I stated the reasons which induced me to believe that the magnetic disturbances of large amount and occasional occurrence, designated in the Report of the Committee of Physics of the Royal Society as the "irregular variations," and perhaps more commonly known by the name of magnetic storms or shocks, would be found, when studied in their *mean* effects on the local magnetic direction and force extending over a sufficient period of time, to have a character of *periodicity*, which if established, would leave no doubt as to the class of magnetic phenomena to which they should be considered to belong. The opinion thus expressed resulted from an examination to which I had subjected the series of two-hourly observations of the Declination in 1841, made simultaneously at Toronto and at Hobarton, and those of 1842 at Toronto; (the corresponding observations for 1842 at Hobarton not having reached England in sufficient time to be included in the examination). Short as this period was, the evidence of the existence of laws of periodical action, connecting the effects of causes operating for the most part simultaneously at distant parts of the globe with the seasons of the year and the hours of the day at particular stations, was sufficiently systematic to induce me to regard this branch of inquiry as a most hopeful one, but as requiring for its prosecution a longer continuance of observations than had been at that time provided for. At Toronto and the other observatories under the Ordnance Department, hourly observations were substituted in 1842 for the two-hourly series previously adopted. It had appeared desirable at the commencement of these establishments not to overcharge them with work; but as it became obvious that whenever a physical theory should be brought forward to explain the phenomena which were the subjects of observation, such as, for example, those of the *diurnal variation*, there would be an immediate demand for the variation observed *at least* at *every* hour, arrangements were made, in the *spirit* of the Royal Society's Instructions, to secure a better provision for the requirements of theory than had been contemplated by the *letter* of those Instructions, and with this view observations at every hour were substituted for observations at every two hours. The series at Hobarton (under the Admiralty) had

been made hourly from its commencement, the personal establishment left by Sir James Clark Ross having been calculated with that view*.

Having lately examined the hourly simultaneous observations of the Declination at Toronto and Hobarton for the years 1843, 1844 and 1845, in the course of their preparation for the press, I have had great satisfaction in finding that they confirm in a remarkable degree the anticipations which I had formed. The general evidence of periodicity, connected with the seasons of the year and the hours of the day in the mean effects at these two distant stations, of causes which yet operate for the most part simultaneously at both, thus furnished by a series of hourly observations continued for three years, is far too systematic, and rests on a basis of too long duration to make it probable that it will be otherwise than confirmed by the continuation of the series in the subsequent years; although the exact periods, and the mean numerical values of the effects produced, or their proportions to each other in the different seasons and at the different hours may, and doubtless will, receive modifications. The term "irregular" can therefore no longer be considered as correctly applied to this remarkable branch of the magnetic phenomena, which studied in their effects must now be regarded as included in the class of "periodical variations." However (apparently) irregular may be the times of their occurrence, as general phenomena affecting contemporaneously parts of the globe most distant from each other, their *effects* at those stations are found to be subject to periodical laws connected with local seasons and local time, indicating a relation directly or indirectly to the sun's place in the ecliptic, and to the earth's diurnal rotation on its axis, and producing a sensible mean effect on the magnetic direction in conformity with their own peculiar laws.

The practical bearing of this conclusion on investigations of a most interesting and valuable character which have recently been brought before the Royal Society, regarding the peculiarities of the diurnal variation in different parts of the globe and their physical explanation, will be evident, when it is considered that we have thus in each day or period of twenty-four hours *two* periodical variations, with laws, as will be seen in the sequel, extremely dissimilar. What commonly has received the name of the "diurnal variation" of the magnetic elements, is their variation at different hours of the twenty-four from a mean value obtained by summing the hourly observations and dividing the sum by their number; or, otherwise expressed, and with reference to the magnetic *direction* only, it is the figure described by either extremity of a free needle in the course of a day, under the influence of *all* causes that may

* The change from two-hourly to hourly observations was accomplished at the Ordnance observatories by adding, with permission of the Master-General of the Ordnance, one non-commissoned officer to the previous strength of the establishment. The extra pay of this artillery soldier for the particular service on which he was employed was fifteen pence a day, or £22 16*s*. 3*d*. a year. This is mentioned because it is not generally known at how small an expense, services of this nature within the competency of the military force stationed in the colonies, can be rendered, whilst the men who are so employed are available for military duty at any moment that may be required.

influence its position, and taken on an average of a sufficient number of days to make the figure a fair mean representation. This is the "diurnal variation," as shown by observation at different seasons and at different parts of the globe, which it has been Mr. FARADAY's object, in papers recently read before the Society, to explain physically. But the variation thus observed is in fact constituted by two variations superimposed upon each other, having different laws, and bearing different proportions to each other in different parts of the globe. At tropical stations the influence of what have been hitherto called the "irregular disturbances" is comparatively feeble, and their periodical effects may be therefore less deserving of attention; but it is otherwise at stations situated as are Toronto and Hobarton, where their influence is both really and proportionally greater, and already amounts to a clearly recognizable part of the whole diurnal variation; and it must be very far otherwise at stations which still more nearly approach those localities on the globe, where disturbances of this class become much greater than either at Hobarton or Toronto. As these localities are approached, the mean diurnal variation must be expected to partake more and more of the law by which the effects of those disturbances are regulated; and if that law be different, as it will be shown to be in the instances adduced in this paper, from another law also shown to exist, and by which another portion of the diurnal variation is governed, it may become necessary, and most probably will become necessary, at such stations, to separate, approximately at least, the effects so regulated by different laws in order to study their respective physical causes.

The Instructions of the Royal Society, which were written before the periodical character of the so-called "irregular" variations was suspected, contemplate that by a sufficiently long continuance of the observations the effects of the "irregular variations" will be self-compensatory. "The observations," it is said, "must be long-continued at the same hours, before we can be assured that the irregularities do not sensibly affect the mean results." But since the true character of the disturbances is now more correctly known, it becomes obvious that no continuance of the observations will render their influence insensible: and the simplification of the problem, in the solution of which Mr. FARADAY is engaged, will require the separation, as far as may be practicable, especially in the higher latitudes, of the two classes of variation which have distinct laws, and therefore probably distinct immediate causes. I venture therefore to hope for the indulgence of the Royal Society in an endeavour to establish the fact of a distinct law of periodical action in the disturbances of occasional occurrence and unusual amount,—to show its general and remarkably analogous character at two stations separated from each other nearly as widely as two stations can be on the surface of the globe, and approximately at least to separate the mean diurnal variations at those two stations into their respective components.

The stations of Toronto and Hobarton are well-situated to furnish observations to be employed in the investigation which forms the subject of this paper. Both stations

are very nearly in the same latitude, but in different hemispheres as respects the equator, and are both extra-tropical; they also differ about fifteen hours of longitude from each other. Simultaneous observations occurring in the winter months of the one station fall therefore into the summer months of the other; and the day observations of the one are for the most part the night observations of the other. The clocks which gave the time for the observations were regulated at both stations to show the mean solar time of the meridian of Göttingen, $9^h\ 15^m$ west of Hobarton, and $5^h\ 55^m$ east of Toronto. The observations were made at the completion of every hour of mean solar time at Göttingen. By this pre-arrangement the whole body of observations during the three years would have been synchronous in respect to absolute time, but for the circumstance that no observations were made on the Sundays, the Christmas days and the Good Fridays; all which days being regulated, agreeably to the purposes for which they were excepted, by *local* time, it followed that in consequence of the difference of meridians between the two stations, there were fifteen observations in each of fifty-four days of each year at each station which had no corresponding observations at the other station. The proportion of these to the whole body of observations is about one-ninth; consequently about eight-ninths of the whole were as strictly synchronous as such observations can conveniently be made. As it is not the object of this paper to examine the precise degree in which the so-called irregular disturbances are synchronous in different parts of the globe, I do not permit myself to enter into details on this part of the general subject, reserving such details for a more appropriate occasion; I will merely state generally that the evidence of the synchronous character of the disturbances afforded by the observations of these three years is not less remarkable than has been stated on other occasions; and I will proceed at once to their distribution into the months and hours of their respective occurrence, first at Toronto and then at Hobarton, and to the evidence afforded thereby of the periodical influence by which their mean effects appear to be governed.

The disturbances to be examined are those which, occurring only occasionally, and apparently irregularly, are indicated by the wide departure of the magnetic instruments from their mean or normal positions at the same hours and at the same period of the year. It is no doubt probable that the causes in which they originate do also produce smaller disturbances of the same class and apparently irregular occurrence; but no characteristics have yet been established by which the smaller disturbances of this class may be distinguished from irregularities in the action of causes of known periodical character and regular occurrence. That such characteristics may exist and may hereafter be recognized, so as to become the subjects of observation and a means of effecting a complete separation between the two classes of phenomena, is also probable; but it is not necessary to wait till then in order to assure ourselves that the larger disturbances, viz. those which may be separated from the others by their magnitude alone, are, notwithstanding their seeming irregularity, subject in their mean values to periodic laws, which are quite distinct from those of any class of disturb-

ances or variations previously recognized; whilst the very large amount of a great portion of them affords a security that the character of their laws of periodicity, derived by a separation in which magnitude alone is regarded as the distinguishing circumstance, is not likely to undergo any material alteration (although the mean numerical values may be slightly altered), should an improved method of discrimination lead hereafter to a more perfect classification.

The magnitude of a disturbance being thus taken as a characteristic feature of the class to which it should be referred, it became a question where the line of separation should be drawn; it was desirable that on the one hand the proportion of separated observations should be ample for the intended purposes of generalization; and that on the other hand the line should be taken sufficiently distant from the mean or normal position, to exclude from the separated observations the disturbances which as far as could be judged might belong to another class. On examination, however, it soon appeared that it was not necessary to be very particular, either at Toronto or Hobarton, in selecting the distance at which the line of separation should be drawn on either side of the normal; the disturbances of *very* considerable magnitude were so numerous, and so far exceeded in amount any changes of regular occurrence, as to make it a matter of very minor importance whether a few more or a few less were comprehended at the lower end of the separated class; and after one or two trials, in which the number of separated observations was varied, but the conclusions were found to be substantially the same, five scale divisions (or 3′·6 in arc), on either side of the mean or normal position of the declination magnet at the same hour and in the same month, were adopted as a convenient distinctive value for a disturbance of the larger class at Toronto.

The number of observations thus separated amounted in the three years (1843, 1844 and 1845) to 1650. The number of hours at which observations should have been made in the three years, exclusive of Sundays, Christmas days and Good Fridays, is 22,392, and the number of hours at which observations were actually made is 22,376, sixteen observations only in the three years having been either missed or being otherwise imperfect; the proportion which the number of separated observations bears to the whole number observed is therefore one in 13·6; and we are thus furnished with an approximate measure, on the average of the three years, of the frequency with which the declination magnet is liable to be disturbed to a certain amount at Toronto, when we say that if observations are made at regular intervals, one observation in every 13·6 on the average may be expected to differ as much as 3′·6 from the true mean position corresponding to the hour and season. In 1843 there were 472 disturbed observations; in 1844, 612; and in 1845, 566; whence we may infer that 1843 was the least disturbed year of the three, and 1844 the most so: and for the purpose of assigning numerical proportions, if the degree of disturbance in 1845 be taken as unity, that of 1844 will be expressed by 1·08, and that of 1843 by 0·84. It ought to be one of the results of the system of simultaneous observation

so generally adopted in the years referred to, that numerical values of this nature, derived from a sufficiently extensive induction, should be comparable with each other, and should assist in determining the great questions, whether disturbances of the class under consideration are wholly general or only partially so; and whether their greater prevalence in particular years, as shown by the observations of any one of the observatories, is to be regarded as a general, or as a local, phenomenon.

If we refer the 1650 disturbed observations to the respective months in which they occurred, the numbers are severally as follows:—

TABLE I.

January	87	July	173
February	101	August	199
March	123	September	232
April	182	October	146
May	130	November	103
June	87	December	97

There are two minima, January and June; the numbers increase from the minimum in January to a maximum in April, and decrease to the second minimum in June; they then increase again to a second maximum in September, followed by a decrease to the minimum in January. The September maximum is greater than the April maximum. If the year be divided into six months of summer and six months of winter, the six summer months, *i. e.* April to September inclusive, have 1003 disturbed observations; and the winter months, *i. e.* October to March inclusive, 657. If the division be into quarters, solstitial and equinoctial, the two equinoctial quarters have the higher numbers, but the summer solstitial quarter (390) is very little less than the spring equinoctial (406); the principal contrast is between the autumn equinoctial quarter (577), and the winter solstitial (287).

If we divide the 1650 disturbed observations occurring in the three years into two portions, one containing the easterly disturbances, or those of the north end of the magnet towards the east, and the other containing the westerly disturbances, we find the number to be 897 easterly and 753 westerly; the easterly preponderating in the proportion of 1·19 to 1.

If we refer the easterly and westerly disturbances separately to the respective months of their occurrence, we have the numbers as follows:—

TABLE II.

Months.	Easterly.	Westerly.	Months.	Easterly.	Westerly.
January	39	48	July	111	62
February	50	51	August	106	93
March	66	57	September	132	100
April	102	80	October	74	72
May	67	63	November	45	58
June	62	25	December	43	54

Whence we perceive, that whether we regard the separate account of the easterly or of the westerly disturbances, we find the numbers increase from a minimum in January to a maximum in April, and decrease to a second minimum in June; that they then commence afresh to increase to a maximum in September, and thence decrease to the minimum in January. With the exception of a small excess of easterly disturbances in July in comparison with August, the progression, which has been found to take place when the combined easterly and westerly disturbances were under consideration, is found to be the same when the separate portions are examined. The minima of each progression are in January and June; the maxima in April and September.

Distinct from this is the conclusion we may obtain if we make an intercomparison of the numbers in the respective columns of easterly and westerly disturbances. By this intercomparison we are led to perceive that in November, December and January, the number of westerly disturbances exceeds the number of easterly; that in the adjacent months on either side, viz. in October and February, the number of each is nearly equal; and that in all the other months of the year the easterly disturbances predominate; the predominance being greatest in June and July. Thus we observe that the causes which produce large easterly deflections of the north end of the magnet, when compared with those which produce westerly deflections, are most influential in June and July, and least so in December and January. Hence, it happens, that the June minimum of westerly disturbance is less than the January minimum, and is the minimum of the year in that portion of the disturbed observations; whilst the January minimum is less than the June minimum of easterly disturbance, and is the minimum of the year in that portion. We find also in the excess of easterly disturbances in June and July, a probable explanation of the small apparent irregularity already noticed in the progression of the monthly numbers in the easterly disturbances, wherein a small excess appears in the July numbers in comparison with those of August. The excess in the total number of disturbed observations in the summer quarter over the winter quarter, appears also to be due to the excess of easterly disturbances occurring in the summer quarter; for if we regard only the westerly disturbances, we find their numbers to be even somewhat greater in winter than in summer (westerly disturbances, November to February, 160: May to July, 150: easterly disturbances, November to February, 127: May to July, 240).

If we now pass to the distribution of the 1650 disturbed observations into the respective *hours* of their occurrence, and seek in the numerical relations which may be thus manifested the evidence which they may afford of the existence of a *diurnal* affection, we may in the first instance examine the number of disturbed observations occurring in each of the hours, independently of the question of whether they are easterly or westerly disturbances: they are as follows:—

TABLE III.

Hours of Toronto time.	Number of disturbed observations.	Hours of Toronto time.	Number of disturbed observations.	Hours of Toronto time.	Number of disturbed observations.
6 A.M.	81	2 P.M.	37	10 P.M.	96
7 A.M.	72	3 P.M.	45	11 P.M.	72
8 A.M.	58	4 P.M.	44	Midnight	89
9 A.M.	66	5 P.M.	35	1 A.M.	83
10 A.M.	71	6 P.M.	46	2 A.M.	78
11 A.M.	69	7 P.M.	62	3 A.M.	80
Noon	61	8 P.M.	77	4 A.M.	78
1 P.M.	55	9 P.M.	101	5 A.M.	90

It is obvious at first sight from this Table that there is a great disparity in the occurrence of disturbed observations during the day and during the night; from 7 A.M. to 6 P.M. inclusive, the average number in each hour is 55, and from 7 P.M. to 6 A.M. inclusive, 82; but the principal contrast is between the hours of the afternoon and those of the night; the average of the five hours, from 2 to 6 P.M., being only 41, or exactly the half of the average of the night hours, 7 P.M. to 6 A.M. But this irregularity of distribution in respect to hours becomes far more striking when the disturbed observations are separated into easterly and westerly disturbances. Commencing with the easterly, we have the following Table:—

TABLE IV.

Hours of Toronto Time.	Number of Easterly disturbances.	Hours of Toronto time.	Number of Easterly disturbances.	Hours of Toronto time.	Number of Easterly disturbances.
6 A.M.	36	2 P.M.	10	10 P.M.	83
7 A.M.	36	3 P.M.	8	11 P.M.	57
8 A.M.	19	4 P.M.	12	Midnight	67
9 A.M.	23	5 P.M.	15	1 A.M.	54
10 A.M.	25	6 P.M.	27	2 A.M.	43
11 A.M.	30	7 P.M.	45	3 A.M.	39
Noon	19	8 P.M.	65	4 A.M.	35
1 P.M.	21	9 P.M.	86	5 A.M.	43

Here we perceive that when the easterly disturbed observations alone are considered, the disproportion of the occurrence in the hours of the day and of the night is much increased, the average number in each hour, from 7 A.M. to 6 P.M. inclusive, being only 20·5, whilst from 7 P.M. to 6 A.M. inclusive it is 54·5. But the hours which are contrasted in an especial degree are from 2 to 6 P.M. inclusive, and from 8 P.M. to 1 A.M. inclusive; the average number of easterly disturbances in each of the five hours, from 2 to 6 P.M., being 14, and in each of the six hours, from 8 P.M. to 1 A.M., 69: the minimum number occurring from 2 to 4 P.M. and the maximum at 8 and 9 P.M.

If we now turn to the westerly disturbances, as shown in the next Table, we find —1st, that they have their minima at the hours when the easterly disturbances have their maxima; and 2nd, that they do not appear to have so marked an epoch of maximum occurrence as do the easterly disturbances.

TABLE V.

Hours of Toronto time.	Number of Westerly disturbances.	Hours of Toronto time.	Number of Westerly disturbances.	Hours of Toronto time.	Number of Westerly disturbances.
6 A.M.	45	2 P.M.	27	10 P.M.	13
7 A.M.	36	3 P.M.	37	11 P.M.	15
8 A.M.	39	4 P.M.	32	Midnight ...	22
9 A.M.	43	5 P.M.	20	1 A.M.	29
10 A.M.	46	6 P.M.	19	2 A.M.	35
11 A.M.	39	7 P.M.	17	3 A.M.	41
Noon	42	8 P.M.	12	4 A.M.	43
1 P.M.	34	9 P.M.	15	5 A.M.	47

In the next Table I have placed the excess in the number of westerly over the easterly disturbances, or of easterly over westerly disturbances, at every hour of the day and night.

TABLE VI.

Hours of Toronto time.	Excess in the number of disturbed observations.	Hours of Toronto time.	Excess in the number of disturbed observations.
6 A.M.	9 Westerly.	6 P.M.	8 Easterly.
7 A.M.	0	7 P.M.	28 Easterly.
8 A.M.	20 Westerly.	8 P.M.	53 Easterly.
9 A.M.	20 Westerly.	9 P.M.	71 Easterly.
10 A.M.	21 Westerly.	10 P.M.	70 Easterly.
11 A.M.	9 Westerly.	11 P.M.	42 Easterly.
Noon	23 Westerly.	Midnight ...	45 Easterly.
1 P.M.	13 Westerly.	1 A.M.	25 Easterly.
2 P.M.	17 Westerly.	2 A.M.	8 Easterly.
3 P.M.	29 Westerly.	3 A.M.	2 Westerly.
4 P.M.	20 Westerly.	4 A.M.	8 Westerly.
5 P.M.	5 Westerly.	5 A.M.	4 Westerly.

We have in this Table a striking illustration of the periodical character of the larger disturbances, in the very different proportion of the numbers of easterly or westerly disturbances prevailing at the different hours. During the hours of the day, or notably from 8 A.M. to 4 P.M., westerly disturbances preponderate, whilst during the hours of the night, or notably from 7 P.M. to the early morning, easterly disturbances preponderate. The average excess in the number of *westerly* disturbances is 19 in each of the nine hours, constituting the former period (8 A.M. to 4 P.M.), and of easterly disturbances 48 in each of the seven hours constituting the latter period (7 P.M. to 1 A.M.). The greatest excess of easterly disturbance occurs at 9 and 10 P.M., when about seven-tenths of the whole number of disturbed observations consists of deflections of the north end of the magnet towards the east.

It is obvious from this systematically unequal distribution in the number of easterly and westerly disturbances of large amount at the different hours of the twenty-four, that unless it should be found on examination that the inequality in the proportion of the *numbers* should be counterbalanced by a similar inequality, but in the opposite

direction, of the *values* of the easterly and westerly disturbances, the general result of the disturbances of this class, viz. those of large amount, must be to produce a *mean diurnal variation* of a distinct character from that which is usually known as such; inasmuch as the periodical law indicated by the last Table is very different in the hours of easterly and westerly deflection, and in those of maxima and minima, or the turning-points, from the law of the diurnal variation derived from the whole body of the observations. The correct inference will then be, that the larger disturbances have a periodical law of their own, regulating their mean effects, and influential on the mean direction of the magnet at different hours of the twenty-four; and that this law is not the same as the periodical law derived from the other observations from which they have been separated. For the purpose of examining this question, which, for the reason already stated, requires that the mean numerical values of the larger disturbances at the several hours should be sought out, I have had the mean diurnal variation for the years 1843, 1844 and 1845 at Toronto computed in two different ways, viz.—1st, from the whole body of the hourly observations, no observation whatsoever being omitted; 2nd, from the same observations, omitting the 1650 disturbances of largest amount separated in the manner described in this paper; that is to say, from the 20,726 remaining observations. In the difference between the two we have the mean diurnal variation produced by the larger disturbances, estimated on the average of the whole period of three years: it is shown in the following Table:—

TABLE VII.

Hours of Toronto time.	Mean diurnal variation produced by the larger disturbances.	Hours of Toronto time.	Mean diurnal variation produced by the larger disturbances.
6 A.M.	0·02 West.	6 P.M.	0·16 East.
7 A.M.	0·02 West.	7 P.M.	0·28 East.
8 A.M.	0·10 West.	8 P.M.	0·56 East.
9 A.M.	0·09 West.	9 P.M.	0·79 East.
10 A.M.	0·06 West.	10 P.M.	0·75 East.
11 A.M.	0·01 East.	11 P.M.	0·42 East.
Noon	0·09 West.	Midnight ...	0·36 East.
1 P.M.	0·02 West.	1 A.M.	0·33 East.
2 P.M.	0·04 West.	2 A.M.	0·20 East.
3 P.M.	0·08 West.	3 A.M.	0·14 East.
4 P.M.	0·03 West.	4 A.M.	0·03 East.
5 P.M.	0·05 East.	5 A.M.	0·00

A glance at this Table is sufficient to show that the periodical law which governs the larger disturbances is quite as clearly manifested, and its systematic character as clearly evidenced, when their mean numerical values are substituted for the numbers of easterly or westerly disturbances occurring at the different hours. It will be best to reserve any further comments until the results have been stated of a similar examination of the observations at the Hobarton observatory in the same three years, 1843, 1844 and 1845.

For the purpose of making this examination, it appeared desirable to separate such a number of the larger disturbed observations occurring during the three years at Hobarton (commencing with the largest), as should bear nearly the same proportion to the body of the observations from which they were separated, as had been the case at Toronto. With this view it was necessary to approximate the line of separation at Hobarton more nearly to the mean or normal position of the magnet than at Toronto; or in other words, to take a lower limit than at Toronto for the deflections of the declination magnet, either east or west of its mean position, which should be classed as belonging to the larger disturbances. The reason is twofold: first, the inclination at Hobarton is nearly 5° less than at Toronto (−70° 38′ at Hobarton, and +75° 15′ at Toronto), whilst the total magnetic force acting on the free needle is nearly the same at both stations; an equal disturbing force will therefore produce a greater deflection of the declination magnet at Toronto, from mechanical considerations, than at Hobarton; and second, that experience has fully shown that the disturbing causes themselves act with greater energy, independently of the mechanical considerations referred to, at Toronto than at Hobarton. It was soon found that a value taken at about two-thirds that at Toronto, viz. 3·4 scale divisions (or 2′·4 nearly in arc), would give nearly the same proportion of separated observations at Hobarton, as 5 scale divisions (or 3′·6 in arc) at Toronto, and this value was accordingly taken.

The number of observations thus separated was 1479; the system of observation being hourly, the total number of observations which should have been made in the three years (Sundays, Christmas days and Good Fridays excepted) is 22,392; the actual number was 21,436; the difference, 956, being occasioned partly by an interruption of several days in June and July 1843, owing to the suspension-thread of the magnet breaking, and partly by observations being occasionally missed, as the hourly system was rather heavy for the establishment which had been left to carry it on. The proportion of separated observations is therefore 1479 : 21,436, or 1 : 14·5; the proportion at Toronto being 1 : 13·6.

The 1479 disturbed observations are composed of 415 in 1843, 562 in 1844, and 502 in 1845; showing, as at Toronto, 1843 to have been the least disturbed year of the three, and 1844 the most so. Taking the number in 1845 as unity, we have the numerical proportions as follows:—

Hobarton		Toronto	
1843	0·83	1843	0·84
1844	1·12	1844	1·08
1845	1·00	1845	1·00

This is quite as near an accordance in the proportion as it would be reasonable to expect, even on the extreme supposition of the disturbances being in all cases common to both stations, as, including the observations missed at Hobarton, between one-sixth and one-seventh of the hourly observations at Toronto were without corresponding simultaneous observations at Hobarton:—

If we now refer the 1479 disturbed observations to the respective months of their occurrence, we have the numbers severally as follows:—

TABLE VIII.

January	208	July	56
February	161	August	102
March	159	September	125
April	148	October	138
May	48	November	123
June	19	December	192

We have here plainly a law of numbers dependent upon the season of the year; but which with some points of resemblance has also some marked points of difference from the law found at Toronto. The number of disturbed observations arrange themselves at Hobarton in a single progression instead of a double progression as at Toronto. The maximum number occurs in December and January, the two midsummer months, and the minimum in May, June and July, the midwinter months. The six summer months, October to March inclusive, have 981 disturbed observations, and the six winter months, April to September inclusive, 498; or on the average nearly twice as many in each of the summer months as in the winter months; whilst at Toronto the proportion is more nearly 1·5 in the summer months to 1 in the winter months. If the year be divided into quarters, the summer solstitial quarter has the greatest number (523); then the two equinoctial quarters (respectively 468 and 365, the numbers at the autumnal equinox preponderating as at Toronto, but the autumn being in this case, February, March and April, instead of August, September and October as at Toronto); and finally, the winter solstitial quarter (123) having here, as at Toronto, a much less number of disturbed observations than the other three.

If we divide the 1479 larger disturbances into easterly and westerly portions (Table IX.), we have 613 deflections of the north end of the magnet towards the east, and 866 towards the west. The predominance is here of westerly disturbances as it was at Toronto of easterly, and as analogy would require, since the stations are in different hemispheres and the deflections are of the same end of the magnet at both. The proportion in which the westerly deflections preponderate is greater than that of the easterly predominance at Toronto, being about 1·4 : 1 at Hobarton and but 1·2 : 1 at Toronto. The westerly disturbances are in excess in every month of the year at Hobarton, whereas the excess of easterly disturbances at Toronto prevails only during seven months of the year, the westerly being in excess during the winter solstitial quarter. But with this difference there is still a considerable analogy preserved; the proportion of easterly disturbances to westerly is greatest in the summer quarter and least in the winter quarter at Toronto, whilst at Hobarton the converse proportion holds good, the proportion of westerly to easterly disturbances being greatest in the summer quarter and least in the winter quarter at Hobarton.

TABLE IX.

Months.	Easterly.	Westerly.	Excess of Westerly.	Months.	Easterly.	Westerly.	Excess of Westerly.
January	80	128	48	July	22	34	12
February.....	73	88	15	August	47	55	8
March.....	70	89	19	September ...	50	75	25
April	69	79	10	October	58	80	22
May	16	32	16	November ...	42	81	39
June	5	14	9	December ...	81	111	30

In this comparison of the laws which appear to regulate the distribution of the larger disturbances in the several months of the year at Toronto and Hobarton, I have been desirous of giving quite as much prominency to the points of difference at the two stations as to those of resemblance; believing the one to be quite as likely to conduct to a recognition of the physical causes of these remarkable phenomena as the other. But it must be remembered that three years scarcely form a sufficient basis of observation for secure and correct deduction of the minor details of an *annual* variation, though they may be sufficient in the case of *diurnal* variation. A continuation of the comparison by a similar examination of the hourly observations at Toronto and Hobarton in the three following years, 1846, 1847 and 1848, may be expected to elucidate what may appear obscure or uncertain on the present occasion, and will enable the differences as well as the analogies of the annual laws at the two stations to be discussed on more secure grounds. I will therefore proceed to the distribution of the 1479 disturbed observations at Hobarton into their respective hours of occurrence, for the purpose of examining the evidence they may afford of a diurnal law, for the deduction of which in its main features at least three years' continuance of observation ought to be a sufficient time.

Table X. shows the number of disturbed observations occurring at each hour of the twenty-four, separating them also into easterly and westerly disturbances.

TABLE X.

Hours of Hobarton time.	Easterly disturbances.	Westerly disturbances.	Total.	Hours of Hobarton time.	Easterly disturbances.	Westerly disturbances.	Total.
6 A.M.	27	21	48	6 P.M.	22	20	42
7 A.M.	38	25	63	7 P.M.	11	33	44
8 A.M.	32	36	68	8 P.M.	10	50	60
9 A.M.	34	24	58	9 P.M.	9	68	77
10 A.M.	36	18	54	10 P.M.	5	66	71
11 A.M.	37	28	65	11 P.M.	7	70	77
Noon	40	33	73	Midnight ...	17	66	83
1 P.M.	41	31	72	1 A.M.	17	67	84
2 P.M.	36	22	58	2 A.M.	16	44	60
3 P.M.	36	22	58	3 A.M.	29	40	69
4 P.M.	37	17	54	4 A.M.	28	27	55
5 P.M.	25	21	46	5 A.M.	23	17	40

If we regard, first, the *westerly* disturbances, we perceive a scarcely less striking disparity in their relative numbers during the hours of the day and of the night than was found to be the case with the *easterly* disturbances at Toronto. From the early

hours of the morning to 6 and 7 P.M., the average number of westerly disturbed observations is considerably less than half the average number during the hours of the night (8 P.M. to 3 A.M. inclusive); whilst the contrast is still greater (as in the case of the easterly disturbed observations at Toronto) between the hours of the afternoon (2 to 6 P.M.) and the early hours of the night (8 P.M. to 1 A.M.).

The hours of the maximum occurrence of the westerly disturbances are also those of the minimum occurrence of easterly disturbances, and the latter do not appear to have any marked epoch of maximum occurrence at other hours.

Referring back to the comments on Tables III., IV., V. and VI., the analogy between the two stations will be seen to be most striking. Laws derived directly from the phenomena, and having so much in common at stations so widely remote from each other, cannot be regarded as accidental, and claim to be viewed as a step gained in the analytical examination of the magnetic phenomena and in their classification; in the path therefore which, according to the principles of the inductive philosophy, conducts from a knowledge of effects to the perception of their cause or causes. We have traced in the largest and most influential portion of the disturbances, belonging to the class which has hitherto borne the name of "irregular," the existence of a law connecting them with the local hours of the station at which they were observed; and in the accordance of this law, as severally deduced at Toronto and Hobarton, we see reason to attribute to it a more general character than that of a mere dependence on the peculiarities of particular stations. In order that this may be more clearly seen, I have placed in the next Table a comparative view of the diurnal variation derived from the larger disturbances at Toronto and Hobarton, on the average of the three years under discussion. The phenomena at Toronto are reproduced from Table VII., and those at Hobarton have been obtained in the same manner as at Toronto, and as is described in the paragraph which immediately precedes Table VII.

TABLE XI.

Local time.	Hobarton.	Toronto.	Local time.	Hobarton.	Toronto.
6 A.M.	0·03 East.	0·02 West.	6 P.M.	0·04 West.	0·16 East.
7 A.M.	0·06 East.	0·02 West.	7 P.M.	0·16 West.	0·28 East.
8 A.M.	0·02 East.	0·10 West.	8 P.M.	0·27 West.	0·56 East.
9 A.M.	0·04 East.	0·09 West.	9 P.M.	0·39 West.	0·79 East.
10 A.M.	0·03 East.	0·06 West.	10 P.M.	0·42 West.	0·75 East.
11 A.M.	0·03 East.	0·01 East.	11 P.M.	0·41 West.	0·42 East.
Noon	0·02 East.	0·09 West.	Midnight ...	0·38 West.	0·36 East.
1 P.M.	0·04 East.	0·02 West.	1 A.M.	0·34 West.	0·33 East.
2 P.M.	0·05 East.	0·04 West.	2 A.M.	0·24 West.	0·20 East.
3 P.M.	0·06 East.	0·08 West.	3 A.M.	0·12 West.	0·14 East.
4 P.M.	0·05 East.	0·03 West.	4 A.M.	0·02 West.	0·03 East.
5 P.M.	0·01 East.	0·05 East.	5 A.M.	0·03 East.	0·00

The general character at the two stations (easterly deflections at the one being equivalent, as already stated, to westerly at the other) is strikingly accordant: the principal difference appears to consist in the mean easterly deflection at Toronto

being greater in amount from 6 P.M. to 10 P.M. than the westerly deflection at Hobarton at the same hours.

The absolute quantities shown in this Table are small, but it must be remembered that they represent the *mean daily* effect of the disturbances, during the whole period of three years under discussion; while the disturbances themselves are by no means of daily occurrence. Small as the numbers are, however, they make a very important change in the character of the residual diurnal variation, both at Toronto and Hobarton, from that which is derived from the mean of all the observations including the disturbed ones. In order that this may be distinctly seen, I have placed in the following Table (XII.) the mean diurnal variation as it would be shown at each hour with and without the disturbances, and have added columns containing the amount of the change in the mean direction in the intervals from hour to hour: the extreme westerly position at Toronto and the extreme easterly position at Hobarton are taken as the respective zeros, from which the diurnal variation at the several hours is counted. The sign + in the column of differences signifies, therefore, that the north end of the magnet has moved during the interval to the east at Toronto and to the west at Hobarton, and the sign − has the contrary signification.

TABLE XII.—Diurnal variation at Toronto and Hobarton, with the disturbed observations retained, and with the same omitted; derived from hourly observations during the years 1843, 1844 and 1845.

Toronto.					Hobarton.				
Toronto mean time.	Retaining the disturbed observations.		Omitting the disturbed observations.		Hobarton mean time.	Retaining the disturbed observations.		Omitting the disturbed observations.	
Hours.	Diurnal variation.	Differences.	Diurnal variation.	Differences.	Hours.	Diurnal variation.	Differences.	Diurnal variation.	Differences.
6 A.M. ...	7·52	+0·91	7·52	+0·91	6 A.M. ...	5·29	+0·76	5·26	+0·80
7 A.M. ...	8·43	+0·24	8·43	+0·33	7 A.M. ...	6·05	+0·98	6·06	+0·93
8 A.M. ...	8·67	−0·93	8·76	−0·95	8 A.M. ...	7·03	+0·52	6·99	+0·54
9 A.M. ...	7·74	−2·25	7·81	−2·28	9 A.M. ...	7·55	−0·61	7·53	−0·62
10 A.M. ...	5·49	−2·63	5·53	−2·70	10 A.M. ...	6·94	−1·77	6·91	−1·77
11 A.M. ...	2·86	−2·08	2·83	−1·98	11 A.M. ...	5·17	−2·30	5·14	−2·31
Noon	0·78	−0·78	0·85	−0·85	Noon	2·87	−2·06	2·83	2·04
1 P.M. ...	0·00	+0·30	0·00	+0·32	1 P.M. ...	0·81	−0·70	0·79	−0·69
2 P.M. ...	0·30	+1·07	0·32	+1·11	2 P.M. ...	0·11	−0·11	0·10	−0·10
3 P.M. ...	1·37	+1·32	1·43	+1·27	3 P.M. ...	0·00	+0·90	0·00	+0·89
4 P.M. ...	2·69	+1·20	2·70	+1·11	4 P.M. ...	0·90	+1·25	0·89	+1·21
5 P.M. ...	3·89	+0·83	3·81	+0·73	5 P.M. ...	2·15	+0·95	2·10	+0·90
6 P.M. ...	4·72	+0·48	4·54	+0·36	6 P.M. ...	3·10	+0·70	3·00	+0·58
7 P.M. ...	5·20	+0·37	4·90	+0·24	7 P.M. ...	3·80	+0·69	3·58	+0·58
8 P.M. ...	5·57	+0·50	5·00	+0·26	8 P.M. ...	4·49	+0·55	4·16	+0·43
9 P.M. ...	6·07	+0·08	5·26	+0·11	9 P.M. ...	5·05	+0·35	4·59	+0·32
10 P.M. ...	6·15	−0·29	5·37	+0·05	10 P.M. ...	5·40	+0·17	4·91	+0·19
11 P.M. ...	5·86	−0·20	5·42	−0·17	11 P.M. ...	5·57	−0·05	5·10	−0·03
Midnight...	5·66	−0·12	5·25	−0·07	Midnight...	5·52	−0·29	5·07	−0·24
1 A.M. ...	5·54	−0·14	5·18	0·00	1 A.M. ...	5·23	−0·31	4·83	−0·22
2 A.M. ...	5·40	+0·17	5·18	+0·23	2 A.M. ...	4·92	−0·31	4·61	−0·19
3 A.M. ...	5·57	+0·46	5·41	+0·57	3 A.M. ...	4·61	−0·06	4·42	+0·05
4 A.M. ...	6·03	+0·55	5·98	+0·58	4 A.M. ...	4·55	+0·23	4·47	+0·29
5 A.M. ...	6·58		6·56		5 A.M. ...	4·78		4·76	

Considering Toronto in the first instance, it is obvious from this Table that the westerly retrogression, which is found to take place from 10 P.M. to 2 A.M. in the diurnal march of the magnetic declination when the whole of the observations are retained, is certainly chiefly, and probably entirely, occasioned by a return of the magnet from the disturbed position to which it had been carried by the great excess of easterly disturbances between the hours of 7 and 10 P.M.; which easterly excess rapidly diminishes after 10 P.M. When the disturbed observations are omitted, the movement of the north end of the needle towards the east after 6 P.M. is seen to be slower, and never reaches so great an easterly extreme as takes place when the disturbed observations (which it must be remembered are only of occasional occurrence) are retained and allowed to influence the daily mean. By the separation of the disturbances of principal magnitude in the manner described in this paper, the westerly retrogression at the hours referred to is in fact almost eliminated, and we can scarcely doubt that it would be entirely so, if we possessed the means of more completely separating the whole of the disturbances which belong to the same class and cause as the larger ones; and that by such separation the character of the residual diurnal variation would be entirely changed (as it is now almost entirely changed) from a double progression having two maxima and two minima, to a single progression with one easterly extreme at 8 A.M., and one westerly extreme at 1 P.M. The change in the character of the diurnal variation at Hobarton, caused by the omission of the disturbed observations, is similar in kind to that at Toronto, though not quite so strongly marked.

The change of character which thus appears to be indicated (at both stations, but particularly at Toronto) is a very important one, as will be readily admitted by those who are engaged in searching out the physical causes of these phenomena. The *nocturnal episode*, as it has been termed by Mr. FARADAY, or the retrogression of the declination during the hours of the night, would be done away as a part of the regular diurnal variation; and the physical explanation which we should have to seek would be that of a different phenomenon, namely, of an *increased* movement, *not* in the *retrograde* direction, but in the *same* direction as that of the regular diurnal variation, occurring at earlier hours of the night than those of the retrogression; being moreover of occasional and apparently fitful (as opposed to regular) occurrence,—although when the average is taken of a sufficient number of days it is found to be strictly periodical in its mean effects, and influential therefore on the mean diurnal variation of the magnet. I wish however to guard myself from being understood to oppose, by these remarks, the supposition that has been made of the existence of physical causes acting during the night antagonistic to those of the day: there may still be room for a supposition of this nature; for admitting the apparent retrogression to be greatly lessened if not entirely eliminated by the withdrawal of the influence of disturbances of occasional occurrence, still it continues to be true that the progression of the residual diurnal variation which commences at an early hour of the afternoon is *checked* during the hours of the night, even if it be not at any moment actually reversed.

Although conclusions which are drawn from hourly observations, continued during three years at two stations, scarcely seem to require the support they may receive from their agreement with inferences previously drawn resting on a much narrower basis, yet it may not be unimportant to recall those, derived from a similar investigation to the present into the two-hourly observations at Toronto in the years 1841 and 1842, which were published by me in 1845 in the Comments on the Observations of those years contained in the first volume of the Toronto Observatory. After remarking that the deflections produced by the disturbances are of sufficient magnitude and regularity of occurrence to constitute a recognizable and systematic component part of the mean diurnal variation obtained from observations of a month's continuance or more, I stated as follows: "By their easterly maximum at 10 P.M. (together with the increasing prevalence of easterly deflections at the previous hours of 6 and 8), there is superinduced an excess of easterly direction at those hours, which appears to be in great measure the cause of the westerly retrogression of the magnet at the succeeding hours of midnight and 2 A.M.; and we are thus led to infer the probability, that if the whole effect of the disturbing cause, or causes, could be eliminated, the residual portion of the diurnal variation might appear as a single progression with but one maximum and one minimum in the twenty-four hours.

"The connection which thus appears between the systematic operation of the disturbances and the occurrence of a double progression in the diurnal variation, would lead to an important inference in regard to the disturbances themselves, to which it may be well to advert, in order that the subject may receive further examination by the observations of other observatories. The hours of the night at which the otherwise continuous easterly march of the diurnal variation is interrupted, appear to be the same, or very nearly the same, at all the observatories at which results have yet been published. If this interruption be either wholly, or in great measure, occasioned by the influence of the disturbances, operating in a systematic manner, as they are found to do at Toronto, the deflections which they produce at other stations must also have a similar systematic character, and be connected, as those of Toronto are, with the hour of the day at the particular station.

"We should in such case arrive at the important conclusion, that whilst the disturbances must be attributed to general causes, inasmuch as they are found to prevail on the same days in different and very remote parts of the globe—it must also be recognized, that their operation, in every particular locality, is regulated by a law which respects the hours of the place."

The investigation, which has been the object of this paper, is obviously incomplete until a similar examination shall have been made of the influence of the larger disturbances on the mean diurnal variation of the Inclination and of the total Force. I may perhaps hope to make such an investigation the subject of a future communication.

VI. *On the Relation of the Air and Evaporation Temperatures to the Temperature of the Dew-Point, as determined by Mr.* GLAISHER'S *Hygrometrical Tables, founded on the Factors deduced from the six-hourly observations made at the Royal Observatory, Greenwich. By* JOHN FLETCHER MILLER, *F.R.S., F.R.A.S., Assoc. Inst. C.E. &c. Communicated by Lieut.-Col.* SABINE, *For. Sec. R.S.*

Received March 14,—Read May 30, 1850.

Remarks.

OF all the instruments observed and recorded by the meteorologist, the hygrometer is in many respects the most valuable, both in a scientific and practical point of view; for, by a simple knowledge of the point at which the atmosphere can contain no more vapour without precipitation at its existing temperature, and which is called the point of saturation or temperature of the dew-point, many other highly important collateral conditions, such as the elastic force of vapour, the weight of vapour in a cubic foot of air, and the additional weight required for complete saturation at all temperatures of the air, the relative degree of humidity, and the weight of a cubic foot of air under the ever-varying circumstances of heat, moisture and pressure, may readily be obtained, either by well-known formulæ, or by inspection from tables prepared for the purpose. But the hygrometer is also of no small value in the arts and in the practical concerns of life: as a prognosticator of the weather it stands second to no other instrument except the barometer, which it often rivals in the faithfulness of its movements; whilst the condition of the air as to moisture or dryness is acknowledged by all physicians to have no slight effect on the human body, both in its normal and abnormal state; but more especially are its influences visible on the frame of the invalid, either in aiding to restore healthy functions, or in promoting the exacerbation of disease.

It is therefore of no small moment that scientific observers, at least, should possess an instrument by which that important element, the dew-point, can be accurately and expeditiously obtained.

DALTON and other old meteorologists made use of glass vessels filled with spring water, which retains a nearly uniform temperature throughout the year; and, in the summer months, it was generally found sufficient to cause a deposit of moisture on the outside surface of the glass. In winter, ice or snow was mixed with the water, or when the temperature was very low, freezing mixtures were employed.

The dew was carefully wiped from the surface of the vessel as long as it continued

to form, and the moment it ceased, the temperature of the water was carefully noted and recorded as the existing dew-point.

This rough and tedious method has however long been superseded by the use of that beautiful and delicate apparatus bearing the name of the late Professor DANIELL, which gives the dew-point at once in degrees of FAHRENHEIT's scale. Highly valuable as this instrument unquestionably is, it is yet open to some objections, more especially in the hands of non-scientific persons.

1st. The reduction of the air temperature to that of the dew-point is effected by the rapid evaporation of sulphuric ether from a hollow ball of glass covered with fine muslin. Now ether is rather an expensive material, and it is essential that it should be unadulterated and of the strongest description, and such cannot always be obtained, even in large towns. An old established and respectable druggist tells me, that until recently (and the practice probably still exists in many places) it was the invariable custom of the trade to mix one part of spirits of wine with every two parts of ether. And I remember examining some ether in use by a young friend who professed to take hygrometrical observations with this instrument, which I should say contained a still larger proportion of alcohol in combination with *water*. This analysis of its composition is based on the fact that it might be used *ad libitum*, without depressing the temperature more than two or three degrees. Long experience has convinced me, that unless the evaporating fluid be pure, the results, if obtained at all, cannot be depended upon. The Ether rect. fort. should, if possible, be employed.

2nd. Some experience, great care and a quick eye, are requisite to secure accurate observations, and to catch the temperature at the exact moment when the annulus of dew begins to form on the dark bulb in the plane of the internal liquid surface.

3rd. If the ether be dropped on the bulb too quickly, too high a dew-point will be obtained. The ether phial should be fitted with a small siphon, and the heat communicated to the fluid by the hand will be sufficient to force it out slowly in drops.

4th. The atmosphere may be so exceedingly dry, particularly in the months of April and May, that no quantity of ether, even of the best kind, will suffice to reduce the temperature to the point of saturation. And this is more especially the case in warm climates, where this fluid deteriorates most rapidly by keeping. At sea, in tropical latitudes, I have sometimes been unable to find the dew-point with DANIELL's instrument for two or three consecutive days.

Such instances are however rare in this country; when they occur, freezing mixtures must be had recourse to, but I have very seldom had occasion to use them. The greatest difference I have ever observed between the temperature of the air and the dew-point, was 28°, on the 27th of April, 1842. The highest dew-point I have recorded was 68°, on the 17th of August, 1843, with 7·53 grs. of vapour in a cubic foot; the lowest was 8°, on the 14th of February in the same year, the air temperature being 26°, and the weight of vapour in a cubic foot only 0·87 gr.

The dry- and wet-bulb thermometers, as a means of obtaining the dew-point, did

not come into use until many years after the invention of DANIELL's instrument, and from the want of correct tables, based on an accurate knowledge of the relation existing between the air and evaporation temperatures and the temperature of the dew-point, they were, until recently, of comparatively little service to the scientific observer.

When the magnetic and meteorological observatory was, at the suggestion of the Royal Society, established at Greenwich, two-hourly observations of the dry- and wet-bulb thermometers began to be taken, whilst the dew-point from DANIELL's hygrometer was recorded every six hours, simultaneously with the temperature of the dry and wet bulbs; and these readings have been continued up to the present time. Such frequent observations, made by careful and competent observers with the best instruments, could not fail in time to afford the requisite data for the computation of an empirical dew-point, at all known temperatures of the air. The volume of Greenwich Magnetical and Meteorological Observations (copies of which the Astronomer Royal is kind enough to send me) for 1843, contains a complete discussion of the results down to 1845, from which the following factors were deduced:—

When the temperature of the air is		the difference between the temperature of evaporation and the temperature of the air multiplied by		gives the difference between the temperature of the air and the temperature of the dew-point.
Between	24° and 25°	"	7°·3	"
Between	25 and 26	"	6·4	"
Between	26 and 27	"	6·1	"
Between	27 and 28	"	5·9	"
Between	28 and 29	"	5·7	"
Between	29 and 30	"	5·0	"
Between	30 and 31	"	4·6	"
Between	31 and 32	"	3·6	"
Between	32 and 33	"	3·1	"
Between	33 and 34	"	2·8	"
Between	34 and 35	"	2·6	"
Between	35 and 40	"	2·5	"
Between	40 and 45	"	2·3	"
Between	45 and 50	"	2·1	"
Between	50 and 55	"	2·0	"
Between	55 and 60	"	1·8	"
Between	60 and 65	"	1·8	"
Between	65 and 70	"	1·7	"
	above 70	"	1·5	"

From these data, Mr. GLAISHER, of the Royal Observatory, in the year 1847, cal-

culated, arranged and printed, at his own cost, an elaborate series of tables, showing, at a glance, the relation of the *temperature of evaporation* to that of the dew-point at every degree of the air temperature, from 10° to 90°; also the elastic force of vapour, weight of vapour in a cubic foot, the remaining quantity required for complete saturation, the relative degree of humidity, and the weight in grains of a cubic foot of air, under the varying conditions of heat, of humidity and of pressure.

Notwithstanding a conviction of the accuracy of Mr. GLAISHER's tables, both from the well-known character of the chief observer and compiler, and the favourable circumstances under which the elements were obtained, yet having found similar tables defective, and having used DANIELL's apparatus with satisfaction for many years, I felt reluctant to abandon it for the wet- and dry-bulb thermometers, slight as is the trouble of observing them, without personal experience of the correctness of the tables by which the dew-point was to be eliminated.

Accordingly, I sent up my DANIELL's hygrometer to Greenwich for comparison with the observatory standard thermometer, and, at the same time, Mr. GLAISHER kindly procured me a pair of delicate thermometers on the same metal frame, selected from a number of others, and made by BARROW of Oxenden Street. These thermometers were considered to have identical readings under similar circumstances, and both to agree with the Greenwich standard. The dew-point thermometer was also found to be generally correct, the errors mostly amounting to small fractions of a degree.

With these instruments the observations embodied in the annexed Tables were made in the years 1847 and 1848, the hours of observing being 11 o'clock in the morning, and 3 o'clock in the afternoon.

Hygrometrical state of the Atmosphere at Whitehaven, in the year 1847.

1847.	Dry bulb.			Wet bulb.			Dew-point.								
							Deduced.			Observed.					
													Compt. of dew-point.		
	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	36·64	38·61	37·62	.....	.....	.....	.....	.....	.....	32·50	33·82	33·16	4·14	4·79	4·46
February	37·17	39·64	38·40	.....	.....	.....	.....	.....	.....	31·14	32·10	31·62	6·03	7·54	6·78
March	43·13	46·34	44·88	.....	.....	.....	.....	.....	.....	36·03	36·09	36·06	7·10	10·25	8·82
April	45·68	47·75	46·71	.....	.....	.....	.....	.....	.....	38·55	39·53	39·04	7·13	8·22	7·67
May	55·70	57·23	56·46	51·46	52·82	52·14	48·40	49·50	48·95	47·96	49·25	48·60	7·74	7·98	7·86
June	59·85	61·75	60·80	54·96	55·63	55·29	51·50	51·00	51·25	51·43	50·98	51·20	8·42	10·77	9·60
July	64·98	67·46	66·22	59·96	61·36	60·66	57·00	57·80	57·40	57·11	57·66	57·38	7·87	9·80	8·84
August	61·53	62·70	62·11	56·87	57·56	57·21	53·90	53·78	53·84	53·95	53·78	53·86	7·58	8·92	8·25
September	55·03	56·26	55·64	50·96	51·11	51·03	48·20	47·30	47·75	47·82	46·68	47·25	7·21	9·58	8·39
October	54·09	53·82	53·95	50·88	50·37	50·62	48·20	46·80	47·50	48·02	47·04	47·53	6·07	6·78	6·42
November	49·85	50·50	50·17	47·59	48·26	47·92	45·40	46·00	45·70	45·57	45·87	45·72	4·28	4·63	4·45
December	41·58	41·28	41·43	39·61	39·23	39·42	37·00	36·80	36·90	37·18	36·71	36·94	4·40	4·57	4·49
Means	50·43	51·94	51·20	51·53	52·04	51·78	48·73	48·62	48·66	43·93	44·12	44·03	6·50	7·82	7·17
				Mean of observed dew-point					48·56	From May		48·56			

Hygrometrical state of the Atmosphere at Whitehaven, in the year 1848.

1848.	Dry bulb.			Wet bulb.			Dew-point.								
							Deduced.			Observed.			Compt. of Dew-point.		
	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.	11 A.M.	3 P.M.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	35·50	36·58	36·04	33·94	34·68	34·31	31·50	31·75	31·62	31·62	31·85	31·73	3·88	4·73	4·30
February	43·16	44·06	43·61	41·85	42·60	42·22	40·12	40·83	40·47	40·05	40·72	40·38	3·11	3·34	3·22
March	43·82	45·46	44·64	41·69	42·68	42·18	39·20	39·50	39·35	39·38	39·26	39·32	4·44	6·20	5·32
April	48·86	51·07	49·96	45·03	46·90	45·96	40·75	42·70	41·72	40·91	42·41	41·66	7·95	8·66	8·40
May	57·57	59·77	58·67	52·80	54·29	53·54	49·45	50·30	49·87	49·40	50·29	49·84	8·17	9·48	8·82
June	60·25	61·21	60·73	55·37	55·51	55·44	52·01	51·48	51·74	52·18	51·29	51·73	8·07	9·92	8·99
July	61·88	64·13	63·00	57·38	58·72	58·05	54·25	55·02	54·63	54·28	55·34	54·81	7·60	8·79	8·19
August	59·22	61·50	60·36	54·32	55·69	55·00	50·87	51·64	51·25	50·80	51·32	51·06	8·42	10·18	9·30
September	58·37	59·91	59·14	54·46	55·32	54·89	51·73	52·11	51·91	51·45	51·64	51·54	6·92	8·27	7·59
October	51·31	51·78	51·49	48·59	48·56	48·57	46·00	45·30	45·65	45·85	45·35	45·60	5·36	6·43	5·89
November	43·99	44·76	44·37	42·17	42·57	42·37	40·04	40·07	40·05	40·14	39·95	40·04	3·85	4·81	4·33
December	42·92	42·89	42·90	41·10	41·24	41·17	38·92	39·14	39·03	39·08	38·35	38·71	3·84	4·54	4·19
Means	50·56	51·93	51·24	47·39	48·23	47·81	44·57	44·98	44·77	44·59	44·81	44·70	5·97	7·11	6·54

In eight months of the year 1847, the difference between the observed and the deduced dew-point is 0°·10, and in 1848 it is but 0°·07, the mean of the two periods comprising 1220 observations, amounting to the comparatively evanescent fraction of $\frac{8}{100}$ths of a degree; and, had the instruments been *absolutely* perfect, doubtless the accordance between the two dew-points would have been still more obvious. Hence the results show, in a striking manner, the extreme accuracy of Mr. Glaisher's Tables, and add additional testimony to the value of the Greenwich hygrometrical observations, and the resulting formula on which those Tables are founded. Being strongly impressed with the utility and importance of these tables, I am induced to give my own experimental evidence in their favour, which (coming from a wholly disinterested party) may perhaps be entitled to some weight; and, in the hope of giving them greater publicity, and of bringing them into that general use which they so well merit, I beg to lay that evidence before the Royal Society.

By means of the tables founded on the Greenwich hygrometrical observations, the combination of the dry- and wet-bulb thermometers is converted into a very delicate scientific instrument, possessing many advantages over that of Daniell, not the least of which is, that its readings may be depended upon, even in the hands of the most inexperienced and uneducated person. Thus, observations on the hygrometrical state of the atmosphere may be obtained on mountains, at great heights above the sea, on the sea itself, in mines, and various other inconvenient localities, by those whose occupations or callings lead them to spend a considerable portion of their time in such situations. In this way illiterate persons may become truly valuable assistants to the meteorologist in his researches, and the observations secured by the shepherd, the miner, and the mariner may afterwards be turned to good account by the philosopher in his closet.

It is however necessary that the thermometers used for this purpose should be essentially good, and, if possible, that their readings should agree with each other,

and with a standard instrument. But as perfect thermometers are very difficult to obtain, most of such instruments will differ from a standard at one point or other of the scale. They should therefore be carefully compared, and the errors allowed for, either at each reading, at the end of every month, or at some stated period. The goodness of the instruments, or the application of the corrections, is the more essential, as any error in either or both the thermometers is considerably increased in the resulting temperature of the dew-point. The bulbs should be carried fully an inch below the metal or wood scale. The wet bulb should be covered with book-muslin, and the best conductor of the water from the cistern to the bulb is a piece of cotton lamp-wick, which must be changed as circumstances require, as in time it is apt to lose its capillary action. In winter, the water in the vessel will frequently be frozen, and the wet bulb quite dry: in this case the bulb must be moistened, when a coating of ice will form on it, from which evaporation will take place: an hour or more will however sometimes elapse before the temperature of the moist bulb falls below that of the dry.

It is well known that evaporation goes on freely from the surface of frozen water, even when the whole mass is converted into a solid block of ice. From the 11th to the 16th of December 1846, during which a brisk breeze prevailed, the loss from my evaporation gauge was 0·450 inch, or ·075 per diem, the average of the month being but ·033 per diem. In twelve days of frost in February, 1847, the evaporation from the ice was ·552, or ·046 per day, the average daily quantity for the month being ·030. During ten days of keen frost, between the 20th and 30th of January, 1848, the ice had parted with 0·324 inch, or ·032 per diem, the average daily loss for the month being only ·024. For five days of December 1848, the loss was ·037 per diem, the daily average for the month being ·032; and from the 1st to the 8th of January, 1849, the depth evaporated was equivalent to ·017 per diem, the average daily loss during the month being ·029 inch. Hence it appears, that notwithstanding the large amount of heat required, not only to liquify but to vaporize frozen water, the vapour thrown off by ice in an invisible form exceeds in amount the average daily evaporation from an equal surface of water in the winter season. This apparently anomalous circumstance probably arises from the extreme dryness of the atmosphere, and its consequently increased capacity for vapour in severe frosts, whereas at other times during the winter the air is very moist near the sea, being generally not more than 2° or 3° above the point of saturation.

The subject of evaporation has been very little investigated or treated of since the publication of Mr. Howard's 'Climate of London' in the year 1818, and having paid considerable attention to this department of meteorology for several years past, I may perhaps be excused (though not directly connected with the issue of this paper) from briefly giving the results of my own investigations, obtained at nearly the opposite point of the kingdom. Evaporation is scarcely ever *entirely* suspended, either during the heaviest rains, or when the air is completely saturated with vapour; at

least, I have not met with more than two or three instances in which some daily loss was not appreciable to a finely graduated metre. In severe nights, the depth evaporated in twenty-four hours will sometimes, though very rarely, reach $\frac{4}{10}$ths of an inch. On the 22nd of May, 1844, 0·430 was measured, and on a freezing mixture being applied to DANIELL's hygrometer, the dew-point was found to be 24° below the temperature of the air, which was 63°. The evaporation for the month was 6·280 inches, with only a quarter of an inch of rain.

Amount of Evaporation at Whitehaven, Cumberland, in the six years ending with 1848.

Month.	1843.	1844.	1845.	1846.	1847.	1848.
	in.	in.	in.	in.	in.	in.
January	·785	·940	·935	1·015	·860	·743
February ...	1·178	1·190	·905	1·335	·843	·792
March.....	1·620	1·835	1·862	2·085	1·821	1·397
April	1·718	2·610	3·400	2·575	2·181	2·728
May	3·045	6·280	3·645	4·375	2·950	4·580
June	4·690	3·820	3·760	6·645	4·506	3·749
July.....	3·125	4·495	5·455	3·450	4·726	3·935
August	3·305	2·520	3·250	3·875	3·751	3·686
September ...	3·745	3·405	3·225	2·980	2·793	2·896
October	1·940	2·270	2·360	1·780	1·688	1·549
November ...	1·030	1·554	1·760	1·360	1·107	1·129
December ...	·800	·800	1·875	1·025	1·005	1·019
Inches.....	26·981	31·719	32·432	32·500	28·231	28·203*

The mean amount of evaporation for the six years is 30·011 inches, and the average quantity of rain for the same period is 45·255 inches, so that the depth of the water precipitated exceeds that taken up by evaporation at the coast, in the latitude of $54\frac{1}{2}°$, by 15·244 inches.

The evaporation gauge with which the above experiments were made, is a copper vessel 8 inches in diameter, and rather more than an inch and a half in depth. Half an inch of water is accurately measured and poured into the dish, and the daily loss ascertained each morning at 9 o'clock, by means of a carefully graduated tube reading to the thousandth part of an inch†.

The evaporation dish receives a fair proportion of wind and sun, and is always exposed in the open air during the day, except when rain is falling. At night, and in wet weather, it is placed under a capacious shed, 9 feet in height, and open in front. Thus, it is conceived, that the evaporating surface is freely acted upon by all the circumstances concerned in promoting this natural process.

Mr. HOWARD found the evaporation near the surface of the ground in the neighbourhood of London to be about 20 inches, or 5 inches under the average fall of

* Evaporation in 1849, 28·699 inches.

† Till the close of 1846, the dish was placed on a stool, 8 inches above the ground; since that period it has been placed on a stand 4 feet 4 inches in height, and just large enough to hold it.

rain; but the gauge was constantly under cover, and consequently but little exposed to the direct rays of the sun, which will account for the great difference between the results at Whitehaven and the metropolis. Had the gauges been in all respects similarly circumstanced, the evaporation at London, from its higher mean temperature, would probably have been found to exceed the amount registered in the higher latitude.

The Observatory, Whitehaven,
October 20th, 1849.

VII. *On the Meteorology of the Lake District of Cumberland and Westmoreland; with a continuation of the Results of Experiments on the Fall of Rain at various heights, up to 3166 feet above the sea level.*

By John Fletcher Miller, *F.R.S., F.R.A.S., Assoc. Inst. C.E.*

Communicated by Lieut.-Colonel Sabine, *For. Sec. R.S.*

Received March 7,—Read May 30, 1850.

Introductory Remarks.

THE Roman numerals at the head of the Tables refer to the same stations as in former years. The gauge at Round Close near Whitehaven has been discontinued, and a new station has been established on the top of Lingmell (which mountain forms the lower part of Sca Fell facing the village of Wastdale Head), so that the number of instruments is the same as in the year 1848.

During the spring, summer and autumn, the mountain gauges are emptied on the last day of each month, whatever may be the state of the weather at the time; but in the winter months, they are of course only examined when accessible, or when the contents are judged to be in a state of partial or entire liquefaction. These gauges have been frozen up since the end of October last; and at the close of the year the higher stations were inaccessible from ice and snow. On the 31st of January, 1850, the whole of the receivers were brought down into the valley, and their contents liquefied by artificial heat.

In severe winters, like the present, I find it difficult to get parties to attend to these instruments, for almost any pecuniary recompense; indeed, so great is the risk of fractured limbs, and the sacrifice of life itself, that even the hardy shepherds shrink from the task of ascending such elevated and rugged peaks as Sca Fell Pike and the Gabel, at this season; and when there is a considerable accumulation of snow on the summits, an occurrence by no means unusual, it is quite impracticable. On the 31st of January, as the person who has charge of the gauges was ascending the Gabel, with two large empty copper receivers fastened together, his foot slipped and he slided down the precipice, a distance of several hundred yards, but fortunately escaped without any material injury. The receivers parted company in the descent, and both of them were literally dashed to pieces. On the same day a shepherd met with a similar accident on Sca Fell, and the injuries he sustained were of so serious a nature as to endanger his life.

I regret that my endeavours to obtain the monthly extremes of temperature on the summit of Sca Fell Pike have hitherto failed.

The indications for 1849 are apparently so erroneous, that I cannot place any dependence upon them. The instruments are slightly inclined in the box, which is riddled with small circular holes, and it is supposed that strong currents of air passing through them have shaken the thermometers, and caused the indices to descend in the tubes. The instruments are now fastened in the case, and I hope to secure correct readings during the current year.

Table I.—Synopsis of the Fall of Rain in the Lake District of Cumberland and Westmoreland, in the year 1849.

No.	I.	II.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	Prevailing winds.		
	Whitehaven.										Eskdale.			Westmoreland.			Borrowdale.					
																	Seathwaite.					
1849.	High Street, 90 feet above the sea.	St. James's Church Steeple, 270 feet above the street, and 160 feet above the sea.	The Flosh, three miles south-east of Whitehaven.	Cockermouth. 126 feet above the sea.	Esseatthwaite Halls, 210 feet above the sea.	Keswick, 358 feet above the sea.	Vale of Gillerthwaite, Finsthwaite, 395 feet above the sea.	Lowwood, 226 feet above the sea.	Foot of Crummock Lake, 283 feet above the sea.	Gatesgarth, 326 feet above the sea.	Centre of Vale.	Head of Vale.	Wastdale Head, 247 feet above the sea.	The How, Troutbeck, 364 feet above the sea.	Ambleside, 190 feet above the sea.	Langdale Head, 350 ? feet above the sea.	In Garden, 6 inches above the surface.	In Field, 18 inches above the surface.	Stonethwaite. 238 feet above the sea.	At Crummock Lake, two observations daily.	At Seathwaite, one observation daily.	At the Coast *, two observations daily.
January.....	in. 5·683	in. 3·517	in. 6·82	in. 7·18	in. 7·36	in. 11·028	in. 14·20	in. 10·545	in. 12·17	in. 17·54	in. 8·97	in. 9·89	in. 21·35	in. 16·858	in. 12·80	in. 25·61	in. 24·96	in. 23·96	in. 20·02	s.w. to w.	s.w. to w.	s.w.
February ...	2·045	1·414	2·63	1·85	2·10	2·260	3·25	2·744	3·38	4·65	3·72	5·57	6·27	4·539	2·92	6·31	7·55	7·25	5·47	s.w. to w.	s.w. to w.	s.w.
March	·837	·435	1·12	1·47	1·94	1·692	3·00	2·135	2·48	3·53	2·07	3·34	4·94	1·641	1·93	4·88	5·51	5·32	3·41	s.w. to w.	s.w. to w.	s.w. & n.w.
April	1·488	1·104	1·60	1·91	2·74	2·358	1·80	2·209	2·91	2·69	2·48	3·03	3·55	1·837	1·72	3·22	3·88	3·78	3·01	n.	var.	n.
May	3·037	2·340	3·17	2·34	2·08	2·364	4·68	3·210	4·21	5·42	3·85	4·56	5·60	3·223	2·92	5·94	6·52	6·07	4·24	s. to s.w.	s. to s.w.	s.w.
June	1·224	·760	1·51	1·41	1·52	1·028	2·80	1·720	2·13	2·24	1·58	1·72	3·29	1·653	1·50	2·86	3·97	3·93	2·64	s.w. to w.	s.w. to w.	s.w.
July	5·478	3·622	6·34	3·91	4·04	5·104	10·07	8·147	9·53	13·94	7·21	8·83	14·29	6·350	6·56	11·01	16·64	16·60	11·18	s.w. to w.	s.w. & n.w.	n.w. var.
August	3·771	4·042	4·27	3·85	4·71	6·126	7·08	4·900	5·38	6·19	5·55	5·84	7·45	5·396	6·92	8·01	9·92	9·27	7·65	s.w. to w.	s.w. to w.	s.w.
September...	2·814	2·043	2·89	2·33	2·04	2·990	4·00	3·220	3·30	3·89	3·42	4·47	4·22	3·793	2·96	4·90	4·08	3·98	3·63	n.	n.	n.e.
October.....	5·252	3·940	6·19	5·43	4·66	5·854	11·60	7·060	11·64	18·25	8·13	9·56	14·84	12·957	11·36	12·79	16·14	15·88	12·54	s. to w.	s. to s.w.	s.w.
November...	4·274	3·462	5·90	4·83	4·80	5·620	9·60	6·270	8·84	13·02	8·54	9·51	14·39	11·023	8·93	15·36	18·75	18·46	14·20	s. to s.w.	s.w. to w.	s.w.
December...	2·396	1·538	2·69	1·88	2·01	2·378	4·33	3·120	4·24	5·73	3·86	4·90	6·83	6·155	4·86	6·94	7·55	7·07	6·28	n.	var.	s.w.
1849.	38·999	28·217	45·13	38·39	40·00	48·802	76·41	55·280	70·21	97·09	59·38	71·22	107·22	75·425	65·32	107·83	125·47	121·57	94·27	s.w. to w.	s.w. to w.	s.w.
1848.	47·342	36·344	60·82	52·37	47·06	66·407	97·73	76·668	98·07	133·55	70·38	86·78	115·32	91·347	77·58	130·38	160·89	157·22	130·24	s.w.	s.w.	s.w.
1847.	42·921	30·713	47·80	42·55	44·45	58·286	80·13	66·296	82·32	106·25	58·66	74·93	96·34	78·004	.....	112·95	129·24	126·80	106·21	westerly.	s.w.	s.w.
1846.	49·134	35·422	55·16	52·41	.....	67·678	83·87	79·249	96·47	121·90	.....	.....	106·93	77·719	.....	127·40	143·51					
1845.	49·207	33·489	53·00	46·93	.....	62·202	76·88	69·542	87·48	124·13	.....	.....	108·55	76·305	.....	136·00	151·87					
1844.	36·723	27·862	39·31	.....	.....	40·629	54·62	49·829	61·46	.....	.....	.....	80·01	51·986								

* The prevailing wind at the coast, in 1849, is between the S. and W.S.W. points inclusive; in the Lake District it appears to have been rather more westerly, or between the S.W. and W. points inclusive; but in these confined narrow valleys, an approximation to the true direction of the under current is all that can be looked for.

Table II.

Wet Days.

1849.	Whitehaven.	The Flosh.	Cockermouth.	Bassenthwaite Halls.	Keswick.	Lowswater Lake.	Crummock Lake.	Eskdale.	Wastdale Head.	Ambleside.	Troutbeck.	Langdale Head.	Seathwaite.	Stonethwaite.
January ...	20	21	20	19	20	22	19	20	22	21	20	22	20	22
February...	12	14	14	12	15	15	14	13	21	12	16	16	17	15
March.....	12	10	12	10	16	11	11	13	20	11	9	12	13	11
April	16	15	21	18	22	21	18	16	25	13	17	18	19	17
May	14	14	15	13	16	17	14	14	18	10	14	15	15	15
June	10	10	8	11	8	9	7	8	12	6	11	9	10	9
July.....	18	19	19	15	17	15	16	17	20	12	16	16	18	15
August ...	19	18	19	17	18	17	17	16	22	13	17	20	18	16
September..	12	10	11	13	14	11	12	11	13	9	11	13	10	12
October ...	17	17	17	18	19	18	22	17	20	16	18	20	18	18
November..	24	22	21	20	20	18	19	18	22	22	22	22	20	19
December ..	15	15	14	16	20	17	16	17	21	14	15	18	15	14
1849.	189	185	191	182	205	191	185	180	236	159	186	199	193	183
1848.	210	207	228	196	229	217	207	205	243	.....	201	212	232	224
1847.	191	183	210	199	204	190	199	.....	226	.....	188	209	202	195
1846.	200	208	234	.....	213	198	216	.....	234	.....	194	213	219	
1845.	193	175	212	.....	195	195	202	.....	211	.....	180	.....	211	

Table III.

Showing the Quantity of Rain received by the Mountain Gauges in thirteen months, between the 1st day of January 1849, and the 31st day of January 1850.

No.	XXI.	XXI.[3]	XXII.	XXIII.	XXIV.	XXV.	XIV.	XIII.	XXVI.	XIX.
	Sca Fell.						The Valley.		Borrowdale.	
1849.	The Pike, 3166 feet above the sea.	Top of Lingmell, 1778 feet above the sea.	Great Gabel, 2925 feet above the sea.	Sparkling Tarn, 1900 feet above the sea.	Stye Head, 1443 feet above the sea.	Brant Rigg, about 924 feet above the sea.	To the west, Wastdale, 247 feet above the sea.	To the south-east, Eskdale, height unknown.	Seatollar Common, 1388 feet above the sea.	The Valley, Seathwaite, 368 feet above the sea.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	21·35	9·89	19·00	23·96
February...	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	6·27	5·57	Frozen.	7·25
March.....	15·53	17·78	17·24	27·17	23·64	18·13	4·94	3·34	7·40	5·32
April	1·48	3·21	1·86	4·14	3·40	4·00	3·55	3·03	2·18	3·78
May	4·42	4·96	4·37	6·20	6·00	4·72	5·60	4·56	3·84	6·07
June	2·75	3·15	3·32	3·71	3·49	2·11	3·29	1·72	2·74	3·93
July.....	11·99	11·85	11·60	13·04	14·50	10·03	14·29	8·83	12·58	16·60
August ...	8·96	7·14	8·10	11·70	10·20	9·14	7·65	5·84	8·60	9·27
September..	4·54	3·30	4·10	4·40	4·87	3·70	4·22	4·47	3·98	3·98
October ...	14·00	15·50	15·00	19·48	15·23	10·93	14·84	9·56	18·30	15·88
November..	Frozen.	12·52	Frozen.	Frozen.	Frozen.	Frozen.	14·39	9·51	12·73 part frozen.	18·46
December..	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	6·83	4·90	Frozen.	7·07
1850.										
January ...	19·52	12·49	19·35	31·26	23·82	24·54	7·26	5·68	17·62	6·46
Inches.....	83·21	91·90	84·92	121·10	105·15	87·30	114·48	76·90	108·97	128·03

Table IV.—For the Summer Months.

No.	XXI.	XXI.²	XXII.	XXIII.	XXIV.	XXV.	XIV.	XIII.	XXVI.	XIX.
	Sca Fell.						The Valley.		Borrowdale.	
1849.	The Pike, 3166 feet above the sea.	Top of Lingmell, 1778 feet above the sea.	Great Gabel, 2925 feet above the sea.	Sparkling Tarn, 1900 feet above the sea.	Stye Head, 1443 feet above the sea.	Brant Rigg, about 924 feet above the sea.	To the west, Wastdale*.	To the south-east, Eskdale.	Seatollar Common, 1388 feet above the sea.	The Valley, Seathwaite, 368 feet above the sea.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
May	4·42	4·96	4·37	6·20	6·00	4·72	5·60	4·56	3·84	6·07
June	2·75	3·15	3·30	3·71	3·49	2·11	3·29	1·72	2·74	3·93
July	11·99	11·85	11·60	13·04	14·50	10·03	14·29	8·83	12·58	16·60
August ...	8·98	7·14	8·10	11·70	10·20	9·14	7·65	5·84	8·60	9·27
September..	4·54	3·30	4·10	4·40	4·87	3·70	4·22	4·47	3·98	3·98
October ...	14·00	15·50	15·00	19·48	15·23	10·93	14·84	9·56	18·30	15·88
Inches.....	46·68	45·90	46·47	58·53	54·29	40·63	49·89	34·98	50·04	55·73

Table V.—For the Winter Months.

1849.	Sca Fell.		Great Gabel.	Sparkling Tarn.	Stye Head†.	Brant Rigg.	The Valley.		Borrowdale.	
	The Pike.	Lingmell.					To the west, Wastdale.	To the south-east, Eskdale.	Seatollar Common.	Valley. Seathwaite.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	21·35	9·89	19·00	23·96
February...	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	Frozen.	6·27	5·57	Frozen.	7·25
March ...	15·53	17·78	17·24	27·17	23·64	18·13	4·94	3·34	7·40	5·32
April	1·48	3·21	1·86	4·14	3·40	4·00	3·55	3·03	2·18	3·78
November..	Frozen.	12·52‡	Frozen.	Frozen.	Frozen.	Frozen.	14·39	9·51	12·73 part frozen.	18·46
December..	Frozen.	Frozen§.	Frozen.	Frozen.	Frozen.	Frozen.	6·83	4·90	Frozen.	7·07
1850. January ...	19·52	12·49	19·35	31·26	23·82	24·54	7·26	5·68	17·62	6·46
Inches.....	36·53	46·00	38·45	62·57	50·86	46·67	64·59	41·92	58·93	72·30

* Sca Fell is situated between the heads of the valleys Wastdale and Eskdale.

† There is a marked deficiency at this station in the winter months, whilst in the summer months the *proportion* is above the average at this altitude.

‡ The receiver was brought into the valley and its frozen contents melted.

§ January 31, 1850. The whole of the receivers were brought down into the valley and their contents liquefied.

TABLE VI.—Temperature at Seathwaite in Borrowdale, in 1849.

1849.	Absolute.		Mean of Max.	Mean of Min.	Approximate mean Temperature.	Mean at 9 A.M.	On Grass.				Prevailing winds.
	Max.	Min.					Min.	Mean.	Radiation.		
									Max.	Mean.	
	°	°	°	°	°	°	°	°	°	°	
January	50	16	40·95	32·82	36·88	36·91	5	29·20	13·2	4·16	s.w. to w.
February	49·8	26	44·85	37·46	41·15	41·07	20	34·77	7·5	3·08	s.w. to w.
March.....	52	26	46·35	36·51	41·43	41·00	21	32·74	12·0	3·54	s.w. to w.
April	60	26	45·98	36·45	41·21	40·71	17·3	32·09	10	4·36	Var.
May	69	36	58·03	45·32	51·67	50·05	27	37·73	15	7·59	s. to s.w.
June	71	40	61·40	48·50	54·95	54·40	28	39·41	15	9·08	s.w. to w.
July	76·3	46	63·11	53·05	58·08	56·79	33	44·85	17	8·19	s.w. and N.W.
August	71·5	44	61·99	53·32	57·65	57·00	32	46·72	13	6·60	s.w. to w.
September	71	39	59·64	46·91	53·27	52·75	26	37·26	15·5	10·03	E.
October	62	30	50·38	40·29	45·33	44·59	21	33·88	11·5	6·41	s. to s.w.
November	59	25	48·35	38·30	43·32	42·10	15	32·16	10	6·13	s.w. to w.
December	50	20	40·35	32·85	36·60	36·80	13	27·25	10	5·60	Var.
1849.	61·8	31·1	51·78	41·81	46·79	46·18	21·5	35·67	12·4	6·23	s.w. to w.
1848.	62·4	30·5	52·15	42·06	47·10	46·76	20·5	35·18	12·9	6·91	s.w.
1847.	62·7	29·9	52·89	42·04	47·46	47·21	.....	.....	.....	.....	s.w.
At Whitehaven.											
1849.	62·3	33·7	53·24	44·15	48·69	.....	18·8	35·05	18·4	9·09	s.w.
1848.	62·9	32·6	53·77	43·79	48·78	.....	20·2	35·73	15·9	8·06	s.w.
1847.	62·2	33·7	53·85	43·50	48·68	.....	21·4	36·05	15·1	7·45	s.w.

Remarks.

As regards the fall of rain, the years 1848 and 1849 have been of a totally opposite character; for, whilst 1848 was by much the wettest, the year 1849 is the driest which has occurred since these experiments were begun in the summer of 1844. In 1849, the vales of Seathwaite, Langdale, Gatesgarth, Buttermere and Loweswater, have received less rain than the average of the four previous years by 20·90 inches, 18·85 inches, 24·36 inches, 20·88 inches, and 17·65 inches respectively; and 35·42 inches, 22·55 inches, 36·46 inches, 27·86 inches and 21·38 inches respectively, less than in the excessively wet year 1848.

It is a remarkable fact, that whilst from one-fourth to one-seventh less rain than usual has descended in the valleys generally, Wastdale Head has obtained nearly half an inch *more* than its average quantity*. It will be observed that the south-west wind has prevailed to an unusual extent in the past year. The south-west is the predominant wind in nine months of 1849, and in the other three months it has been the same current which brought the rain. Now, whereas the valleys in general open out towards the north-west, the Vale of Wastdale directly faces the south-west, and a cur-

* The rain was read off and recorded by the same registrar as in former years, and there can be no doubt of the correctness of the returns. That this instrument must have been attended to with the greatest regularity, is evident from the fact of there having been 236 measurements of rain at Wastdale Head in 1849, a number considerably exceeding the wet days at any other station, so that the smallest appreciable portions must have been recorded.

rent from that quarter flows freely up the valley without any intervening object to obstruct its progress; so that an extraordinary prevalence of south-westerly winds might be expected to increase the amount of rain at Wastdale, and to diminish it in the other valleys; and *vice versâ*, with a long continuance of north-westerly winds. Troutbeck, which is similarly situated to Wastdale, has only received about 5 inches, or one-sixteenth less than the average quantity.

The wet days at Wastdale are generally about sixteen more than at Seathwaite, the wettest of the stations; but in 1849, they are forty-three in excess, and thirty-one more than have been recorded in any other part of the Lake District.

This may be accounted for from the fact, that the mountains surrounding the Head of Wastdale are both the highest and the nearest to the sea; their elevated peaks attract the clouds, and occasionally deprive them of the *whole* of their water; and such appears to be more particularly the case in dry seasons and periods. Hence Wastdale is visited with many showers which never reach the more inland valleys. The increase in the annual depth of rain from this cause is, however, very trifling.

Gatesgarth, which usually obtains about one-fifth more rain than Wastdale, in 1849 has received nearly 10 inches *less*; and in the latter half of the exceedingly dry year 1844, I find that the excess was also in favour of Wastdale.

These abnormal results are evidently the effect of the position or bearing of the respective valleys in regard to the prevalent wind. Wastdale may be said to receive the south-west wind with open arms; but, at Gatesgarth, it traverses the narrow valley and its mountain ridges nearly at right angles.

The wettest days in 1849 were the 24th of January and the 24th of October; on the former there fell 4·30 inches at Seathwaite, and on the latter 4·37 inches at Wastdale Head. In four days, between the 22nd and 25th of October, the fall at Wastdale was 9·94 inches, and at Seathwaite 10·79 inches.

The average depth of rain in the different valleys throughout the Lake District during the last five years, is as under:—

	inches.
High Street, Whitehaven	45·52
St. James's Church Steeple, Whitehaven	32·84
The Flosh, three miles south-east of Whitehaven	52·38
Cockermouth	46·53
Bassenthwaite (three years)	43·83
Keswick	60·67
Gillerthwaite, Ennerdale	83·00
Loweswater Lake	69·40
Crummock Lake	86·90
Gatesgarth	116·58
Eskdale, middle of vale (two years)	64·88
Eskdale, head of vale (two years)	79·00

	inches.
Wastdale Head	106·87
Ambleside (two years)	71·45
The How, Troutbeck, Westmoreland	79·76
Langdale Head, Westmoreland	122·91
Seathwaite, Borrowdale	142·19
Stonethwaite, Borrowdale (two years)	112·25

In my last paper I stated that the inhabitants of the Lake District valleys enjoyed a milder and more equable climate than the residents in the open country, and particularly in the winter months. This remark is confirmed by the thermometrical results of the present winter, as will be seen by inspecting the following comparative table:—

1849.	Seathwaite.				The Flosh, Whitehaven.				Cockermouth*.	
	Mean of max.	Mean of min.	Mean temperature.	Absolute min.	Mean of max.	Mean of min.	Mean temperature.	Absolute min.	Mean of min.	Absolute min.
November ...	48°·35	38°·30	43°·32	25°	45·56	35·50	40·53	20°	37°·73	22°
December ...	40·35	32·85	36·60	20	39·39	29·32	34·35	18	31·55	20
1850.										
January	36·88	28·42	32·65	19	34·45	25·48	29·96	14	27·16	14
Means.....	41·86	33·19	37·52	19	39·80	30·10	34·94	14	32·14	14

Seathwaite is about fourteen miles inland. The Flosh is three miles south-east of Whitehaven, and the same distance from the sea in the direction of the mountains. Cockermouth is about six miles from the nearest part of the coast, and eight miles nearer to the sea than Seathwaite. Now places situated on the west coast of England are generally warmer than more inland localities; and, were the whole country a vast plain, the temperature would probably be found to diminish with some regularity in proportion to the distance from the western ocean; but from the operation of causes referred to in a former paper, the mountain district of Cumberland is an exception to the general fact.

At Seathwaite, the thermometer on the grass has been below the freezing-point in every month of 1849, except July, when it was 1° above it; and the mean of the whole absolute minima is 10°·5 below the point of congelation.

In January, this thermometer was at or below 32° on seventeen nights; in February, on ten nights; in March, on fourteen nights; in April, on fifteen nights; in May, on eight nights; in June, on six nights; in July, on 0 nights; in August, on two nights; in September, on nine; in October, on sixteen; in November, on fifteen; and in December, on twenty-four nights. The thermometer used for showing the temperature at the surface is a common Rutherford; had a more delicate instru-

* The maximum thermometer was not recorded at Cockermouth in 1849.

ment been employed for the purpose, the mean of the terrestrial radiation would probably have been about a degree higher than the result shown in the table. A naked thermometer under pretty similar circumstances, at Whitehaven, has been below 32° in every month of last year, viz. in January, on nineteen; in February, on fourteen; in March, on thirteen; in April, on eighteen; in May, on eleven; in June, on eight; in July, on one; in August, on two; in September, on five; in October, on sixteen; in November, on thirteen; and in December, on twenty-four nights. The mean of the whole minima is 18°·8.

The Mountain Gauges.—On the whole, the results are similar to those of the three preceding years, but, as might be looked for in a dry year like the past, the quantities deposited at the various stations are more nearly equal than usual; in other words, the differences are not so great or striking as obtain in either wet or average periods.

A trifling change in the position of the gauge on Seatollar Common in Borrowdale, has led to some rather startling results, which promise in time to guide us to the proximate cause of the enormous excess of rain in this valley over every other in the Lake country. It is expected that this gauge (Seatollar, supposed to be 1300 feet above the sea), which has hitherto obtained about one-fifth *less*, will in future impound quite as much, or even more rain than the noted vale of Borrowdale.

The year 1849 has not enabled me to add any new fact of importance to those already communicated to the Royal Society in reference to this part of the inquiry; and as the past annual period has evidently been of an anomalous character, I think it better to avoid drawing any inference or conclusion from the results which it has afforded. I am the more inclined to defer deductions to a future time, from the circumstance of my having been compelled to estimate the heights of some of the mountain stations, which have never been measured; and because I hope to have an opportunity of taking the altitudes myself in the course of the ensuing summer. These scanty remarks must therefore be regarded as a mere supplement to the papers previously printed in the Philosophical Transactions.

The Observatory, Whitehaven,
February 11, 1850.

VIII. *On the Structure of the Membrana Tympani in the Human Ear.* *By* JOSEPH TOYNBEE, *F.R.S., Fellow of the Royal College of Surgeons of England, Aural Surgeon to St. Mary's Hospital, and Consulting Surgeon to the St. George's and St. James's General Dispensary.*

Received June 19,—Read June 20, 1850.

IN conducting researches into the pathological condition of the organ of hearing, I have been impressed with the necessity of ascertaining, with as much precision as possible, the intimate structure of the various tissues entering into its composition. The results to which investigations undertaken with this latter object in view have led me, in reference to the structure of the membrana tympani, it is the purpose of the present paper to detail. It will be observed that the conclusions at which I have arrived, differ materially in various important particulars from those of previous investigators.

Examined from the exterior, inwards the membrana tympani consists of the following layers:—

1. The epidermis.
2. The proper fibrous layer, composed of—
   a. The lamina of radiating fibres.
   b. The lamina of circular fibres.
3. The mucous membrane (Plate III. fig. 1).

1. The *epidermis* is a thin layer covering the outer surface of the radiating fibrous lamina; it is continuous with the epidermis of the external meatus, and when subjected to the process of maceration it can be removed in the form of a small blind pouch, which presents, as it were, a cast of the meatus and of the external surface of the membrana tympani. When floating in water the pouch assumes the form it had when in contact with other tissues, and its internal extremity is convex, corresponding with the external concavity of the membrana tympani (fig. 2). The layer of epidermis forming the outermost coat of the membrana tympani is thin, and in the living subject so transparent that the radiating fibrous layer is distinctly seen through its substance: its outer surface is very smooth and capable of reflecting light: this layer presents no appearance of an orifice.

2. The *proper fibrous layer* of the membrana tympani can be easily separated into two laminæ, which, on account of the direction of their component fibres, may be called the radiating fibrous and the circular fibrous laminæ. Previous to entering upon an examination of these structures, it is desirable to cite the opinions which eminent anatomists have entertained on the subject.

In the Croonian Lecture, published in the nineteenth volume of the Philosophical Transactions, Sir EVERARD HOME advanced the opinion that the membrana tympani in the human subject was muscular. His words are, "When viewed in a microscope magnifying twenty-three times, the muscular fibres are beautifully conspicuous, and appear uniformly the same throughout the whole surface. There being no central tendon as in the diaphragm, the muscular fibres appear only to form the internal layer of the membrane, and are most distinctly seen when viewed on that side*." The use of this radiated muscle, Sir EVERARD HOME states, is "to give those different degrees of tension to the membrane, which empower it to correspond with the variety of external tremors†." Since the first publication of this opinion as to the muscularity of the membrana tympani, anatomists have generally conceded that it is fibrous, but they have widely differed as to its composition. According to Mr. QUAIN and Dr. SHARPEY, "it is made up of fine closely arranged fibres, the greater number of which radiate from near the centre to the circumference; but within these are circular fibres which are more scattered and indistinct, except close to the margin of the membrane, where they form a dense, almost cartilaginous ring‡." Mr. WHARTON JONES writes, "The proper membrane can be divided into two layers, an outer thin one, consisting of radiating fibres, and an inner thicker layer, which is less distinctly fibrous, though when torn it does indicate a fibrous disposition, and that in a direction opposite to the former..... The fibres which cross the radiating ones are also more aggregated at the centre. They run parallel with the handle of the malleus and turn round its extremity. At the circumference of the proper membrane there is a thick firm ligamentous or cartilaginous ring, which is fixed in the groove of the bone. The ligamentous ring appears to be formed by an aggregation of the circular fibres interwoven with the peripheral extremities of the radiating ones§."

By careful dissection the fibrous layers of the membrana tympani may be separated into two distinct laminæ, the fibres of which have no communication with each other. The external layer may be called the *radiate fibrous lamina*, on account of its fibres radiating from the malleus to be attached to the cartilaginous ring, and the internal the *circular fibrous lamina*. The radiate layer is the thicker and stronger. So readily may the two layers be separated from each other, that they are detached with greater facility than that with which the circular layer can be removed from the mucous membrane.

a. *The Radiate Fibrous Lamina.*

If the whole of the membrana tympani be carefully removed, there will be observed at its circumference a white dense ring, apparently cartilaginous, which is received into the osseous groove of the temporal bone appropriated to it. It will be remembered however that this groove occupies only about five-sixths of the circumference of the inner extremity of the meatus, the upper sixth being smooth instead of grooved.

* *Loc. cit.*, p. 5. † P. 11. ‡ Elements of Anatomy, fifth edition, 1848, vol. ii. p. 932.
§ Cyclopædia of Anatomy and Physiology, vol. ii. p. 545.

The cartilaginous ring at the upper part is attached to the malleus, the anterior extremity being inserted into the anterior part of the cervix of this bone, and the posterior extremity into its posterior part; the outer surface of this ring has attached to it the periosteum, lining the external meatus (fig. 3). If the radiate lamina be examined with a magnifying power of ten or twelve diameters, fibres will be observed whose peripheries are attached to the cartilaginous ring, and their other extremities to the malleus. The uppermost of these fibres, however, must be excepted from the observation just made, for instead of passing from the superior part of the cartilaginous ring to the malleus, they take their course in front of the processus brevis and form a distinct layer of membrane covering its outer surface (fig. 3). The disposition of this portion of the radiating fibrous lamina is interesting alike to the anatomist and to the surgeon, for it is observed to be continuous with the periosteal lining of the upper part of the external meatus. Mr. SHRAPNELL, perceiving that this portion of the membrana tympani was not so tense as the rest, considered it to be a distinct structure, and named it the "membrana flaccida*."

Directly below the processus brevis of the malleus the radiating fibres are attached to the ridge occupying the external surface of the bone, but at this part the fibres from each half of the membrana tympani are inserted so near to each other that no portion of the malleus is visible when viewed exteriorly; towards the inferior extremity of the long process, however, the fibres are attached to the sides and not to the anterior surface, and thus a small portion of the external surface of the long process at its inferior part is left bare and is in contact with the epidermoid layer, as may be distinctly seen in the healthy living ear by means of the speculum auris and a magnifying lens. The fibres extending from the malleus and forming the posterior segment of the membrane, are one-fourth longer than those forming the anterior segment. The thickest part of this layer is that which surrounds the extremity of the long process of the malleus, and the most attenuated is that which lies between the posterior margin of the long process of the malleus and the circumference of the membrana tympani†.

Structure of the Radiate Lamina.

The fibres composing the radiate lamina, when examined in a fresh state by the microscope, are translucent, and with the exception of a few transparent granules, present no peculiarity of structure; the longitudinal parallel wavy lines, characteristic of ordinary fibrous membranes, are absent. These fibres are flat, and vary from a 4000th to a 5000th part of an inch in breadth (fig. 5). In passing from the circular

* Medical Gazette, vol. x.

† The blood-vessels ramifying in the upper part of the membranous lining of the external meatus are freely continuous with those of the membrana tympani. These blood-vessels are connected by cellular tissue, and the two together often form a distinct layer of membrane covering the outer surface of the upper part of the external radiate fibrous lamina (fig. 4). See Appendix.

cartilage to the malleus these fibres interlace with each other, from whence originates the peculiar diamond-shaped markings observable on the outer surface of the membrane (fig. 6). When treated with acetic acid this lamina becomes opake, and sometimes elongated oval nuclei are observed, the long axes of which correspond with the course of the fibres (fig. 7). These nuclei are by no means invariably to be detected, and in several specimens they were not apparent on the application of the acid. In no instance was an oval nucleus visible in an isolated fibre.

The *circular white band* at the circumference of the radiate fibres consists of a firm mass of tissue, which is slightly elastic. It presents an indistinct appearance of fibres intermixed with oval-shaped nuclei. Upon the application of acetic acid this structure loses its white aspect, becomes translucent, and discloses a greater number of the oval nuclei (fig. 8).

b. *The Circular Fibrous Lamina.*

This membrane is attached to the radiating fibres by fine cellular tissue, and, as previously stated, the two structures can be separated with facility; the fibres of each lamina are quite distinct and never intermingle. The circular lamina consists, as its name implies, of circular fibres; they are firm and strong at its circumference, but towards the centre they are so attenuated as to be detected only by considerable care. The strong fibres at the circumference of the layer form a complete circle, and are attached to each side of the body of the malleus and to the sides of the upper third of the *processus longus* (fig. 9). When carefully examined by a magnifying power of thirty to forty diameters, these circular fibres are observed to be intersected by others of an extremely delicate character; these delicate fibres are more numerous towards the central part of the lamina, where they are so intimately blended with the circular fibres that the latter are not easily distinguished (fig. 10). The central thin portion of the circular lamina is not attached to the malleus, but the fibres from each side are continuous, and they form a membranous layer composed of a series of concentric fibrous circles. The outer surface of this central portion of the lamina is in contact with the inner surface of the lower half of the long process of the malleus, to which it is adherent by loose cellular tissue. The circular fibrous lamina is entirely unconnected with the cartilaginous ring into which the radiating fibres are inserted, but it is continuous with the periosteal lining of the tympanic cavity, of which it may be considered a modification. When the lamina of circular fibres is detached from that of the radiating fibres, it will be found to be slightly concave externally, though not to the same extent as the outer layer. In its separate condition it becomes rather less concave than when it was applied to the inner surface of the radiating fibres, and when its central portion is pressed inwards so as to increase its concavity, its inherent elasticity causes it quickly to resume its former shape, resembling that of a saucer. If the two layers be detached from each other and placed side by side, the greater degree of concavity externally of the radiating fibrous layer is very perceptible.

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Structure of the Circular Lamina.

When highly magnified, the fibres composing the circular lamina are found to be smaller than those constituting the radiate fibrous layer; they vary in size from the 6000th to 10,000th of an inch in breadth. The outer fibres run parallel with each other, and do not interlace so much as the radiating fibres; they are diaphanous, and do not present any wavy longitudinal lines (fig. 11). When acetic acid is applied the fibres enlarge and assume a certain degree of opacity, and in some instances this lamina also has presented distinct oval nuclei, elongated in the direction of the fibres (fig. 12). Like the radiate lamina, the separate fibres were never observed to reveal the existence of nuclei, and as a general rule their presence in the tissue is not detected.

It is often not easy to decide whether a structure is muscular, and doubts may arise as to the real nature of the two fibrous laminæ of the membrana tympani. My own researches do not seem to favour the view of that membrane being a contractile tissue.

The facts which seem to militate against the idea of its being muscular are,—

1st. The absence of distinct nuclei in the fibres.

2nd. Their great denseness and hardness, their firm and unyielding structure, they being so strong that it is with some difficulty they can be torn across.

The *mucous membrane* forming the inner layer of the membrana tympani is in the healthy ear so extremely thin that its presence is with difficulty detected; by careful dissection however it can nevertheless be removed entire from the inner surface of the circular fibres, to which it is connected with considerable firmness by fine cellular tissue.

It will now be evident that of all the laminæ which constitute the membrana tympani not one is proper to the organ, all of them being directly continuous with other structures, of which they appear to be modifications*. Thus:—

1st. The *epidermis* is continuous with that lining the external meatus.

2nd. The *radiate fibrous lamina* is a prolongation of the periosteal lining of the external meatus.

3rd. The *circular fibrous lamina* is a prolongation of the periosteum of the tympanum.

4th. The layer of *mucous membrane* forms part of the lining of the tympanic cavity (fig. 13).

Previous to considering the functions of the fibrous laminæ of the membrana tympani, it is desirable to advert to another point in the structure and relations of this organ. It has been already stated that the membrana tympani is attached at its circumference to the temporal bone, and at its central part to the malleus. The

* See Appendix.

latter bone is so suspended by means of the processus gracilis and the short process of the incus*, that the long process can move inwards towards the tympanic cavity, and outwards towards the meatus (fig. 14). It must be evident, therefore, that in order to prevent the concave membrana tympani, with the above attachments, from remaining in a state of relaxation, either the tensor tympani muscle must be in a state of continual contraction, or some other provision must exist for retaining the membrana tympani in the moderately tense condition fitting it to receive the sonorous undulations. The provision which actually exists, and which, so far as I am aware, has hitherto escaped the attention of anatomists, is the *tensor ligament of the membrana tympani*.

The ligament in question is about three-fourths of a line in length, and it is attached internally to the cochleariform process, and externally to that part of the inner surface of the malleus where the long process joins the neck (fig. 15). In the interior of this ligament, which presents a tubular shape, is placed the tendon of the tensor tympani muscle. It is thin anteriorly, where it consists of very delicate fibres, but the remainder is thick and dense, being composed of firm ligamentous tissue. So long as this ligament remains entire and the membrana tympani uninjured, the latter structure retains its natural degree of concavity and tenseness; but upon the ligament being cut through, or upon a solution of continuity being effected as the result of disease, the membrana tympani becomes very flaccid, even though the tendon of the tensor tympani muscle remains entire. In a preparation, when the tensor tympani muscle is pulled†, the membrana tympani is rendered very tense, and the tensor tympani ligament is relaxed; but immediately that the muscle is relaxed the membrana tympani is observed to return to its usual state, and the ligament is again rendered tense.

On the Functions of the Fibrous Laminæ of the Membrana Tympani.

It is obvious that one use of the fibrous laminæ of the membrana tympani is to present a firm but delicate membranous septum for the reception of sonorous undulations. The arrangement of the two sets of fibres at right angles to each other has

* The short process of the incus is attached to the margin of the mastoid cells by ligamentous fibres, which allow of a lateral motion only.

† The tensor tympani muscle has an attachment which appears not to have been hitherto noticed. The tendon is generally described as passing backwards from the muscle, and then turning outwards over the cochleariform process to be attached to the malleus; but previously to changing its direction this tendon is very firmly attached by strong ligamentous tissue to the posterior extremity of the groove of the tensor tympani muscle (fig. 16). When the muscle contracts, these ligamentous fibres are put on the stretch, and the portion of the tendon that passes to the malleus being also stretched, the malleus is drawn in, and the membrana tympani rendered tense; but with whatever degree of force the muscle may afterwards be pulled, the membrana tympani itself is not rendered more tense in the slightest degree, the whole strain being on the above-described ligamentous fibres attached to the groove. If these fibres are cut through and the muscle be tightly drawn, the membrana tympani is ruptured.

the effect of imparting great strength to the membrane, while it preserves its extreme delicacy and tenuity. It has been stated that there is no evidence to prove that the fibres, of which the membrana tympani is composed, possess in themselves any contractile power; neither do the component fibres of the laminæ appear to evince more than an extremely slight degree of elasticity. An examination however of the structure after death shows that it has an inherent power of returning to its natural state of tension after being unusually distended. Thus, if the membrana tympani be exposed without interfering with its natural state of tension, and the canal containing the tensor tympani muscle be laid open, so that that muscle can be drawn towards its origin, the external concavity of the membrana tympani can be increased till it becomes very tense, but as soon as the muscle is let go the membrana tympani will be observed to resume its former condition. This action is explainable partly by the slight elasticity of the circular cartilaginous band, into which the peripheral extremities of the radiating fibres are inserted, and partly by the slight elasticity of these fibres themselves, but more especially by the peculiar arrangement of the circular fibrous lamina, which it will be remembered has always a tendency, when left to itself, to assume a more shallow form. Thus, when the membrane is rendered very concave, the circular fibres are slightly separated from each other; but when the extra tension ceases, the fibres intersecting the circular ones aid in drawing the latter together again.

The disposition of the central part of the circular lamina also assists it in the function of bringing back the membrana tympani to its natural state after tension by the tensor tympani muscle. It has been stated that the middle part of these circular fibres, instead of being attached to the handle of the malleus, are applied against its inner surface, and thus the membrane is rendered tense by the pressure of the long process of the malleus against its outer surface during the action of the tensor tympani muscle, and when this muscle ceases to act the central part of the circular layer of fibres reacts on the malleus, and constrains it to resume its usual position. Besides the office of bringing the membrana tympani to its natural state after the action of the tensor tympani muscle, the circular fibrous layer would appear to be always acting as an antagonist to the tensor tympani ligament, and by the continued action of these two tissues, the one drawing it inwards, the other outwards, the membrana tympani is kept in a state adapted to receive all the ordinary sonorous undulations, independent of the exercise of any muscular power.

Explanation of the Figures.

PLATE III.

Fig. 1. The epidermoid layer having been removed by maceration, the two fibrous laminæ and the mucous membrane are seen partially separated by dissection. (Natural size.)

Fig. 2. The tubular cul-de-sac formed by the epidermis lining the external meatus; the inner extremity corresponding with the membrana tympani is convex. (Natural size.)

Fig. 3. The radiate fibrous lamina of the membrana tympani; the fibres of which it is composed extend between the cartilaginous ring and the malleus, with the exception of the uppermost fibres, which are not inserted into the malleus. (Slightly magnified.)

Fig. 4. The external surface of the membrana tympani, the epidermoid layer having been removed; the upper part of the membranous meatus is seen to be continuous with a membrane covering the upper and outer surface of the radiate fibrous lamina. [This membrane is the dermoid lamina of the membrana tympani; it is described in the Appendix to the paper as covering the whole of the outer surface of the radiating fibrous lamina.]

Fig. 5. The fibres composing the radiate fibrous lamina. (Magnified about 300 diameters.)

Fig. 6. The radiate fibrous lamina, external surface displaying the peculiar markings caused by the interlacement of the fibres. (Magnified about 300 diameters.)

Fig. 7. The radiate fibrous lamina after having been treated with acetic acid.

Fig. 8. The circular cartilaginous band after having been treated with acetic acid.

Fig. 9. The external surface of the circular fibrous lamina; the fibres being attached to the processus longus of the malleus. (Slightly magnified.)

Fig. 10. The internal surface of the circular fibrous lamina; the long process of the malleus is seen through the translucent central part. (Slightly magnified.)

Fig. 11. The fibres composing the circular fibrous lamina. (Magnified about 300 diameters.)

Fig. 12. The circular fibrous lamina after being treated with acetic acid.

Fig. 13. The radiate fibrous lamina, the circular fibrous lamina and the mucous membrane of the membrana tympani seen to be continuous with other structures. (Slightly magnified.)

Fig. 14. The attachment of the incus and malleus, illustrative of the movements of the incus, malleus and membrana tympani.

Fig. 15. The attachments of the tensor tympani ligament; the tendon of the tensor tympani muscle is drawn upwards so as to expose the ligament.

Fig. 16. The insertion of the tensor tympani muscle and its attachment by strong ligamentous fibres to the inner part of the base of the cochleariform process.

Appendix to a Paper "On the Structure of the Membrana Tympani in the Human Ear." By JOSEPH TOYNBEE, *F.R.S., Fellow of the Royal College of Surgeons of England, Aural Surgeon to St. Mary's Hospital, and Consulting Surgeon to the St. George's and St. James's General Dispensary.*

IN a note at p. 161 of the above paper, I have stated that "the blood-vessels ramifying in the upper part of the membranous lining of the external meatus are freely continuous with those of the *membrana tympani*. These blood-vessels are connected by cellular tissue, and the two together often form a distinct layer of membrane, covering the outer surface of the upper part of the radiate fibrous lamina (fig. 4)." Since writing the above lines I have had opportunities of making several careful dissections of the membrane alluded to, and the result of these dissections is to demonstrate that between the epidermoid and radiating fibrous layers of the *membrana tympani*, there is a distinct and complete lamina of membrane which is continuous with the dermoid layer of the meatus. The presence of this membrane, to which, on account of its structure and functions, I have given the name of *dermoid layer*, is best demonstrated by carefully dissecting under water the membranous meatus from the upper surface of the osseous tube as far as the attachment of the membrani tympani; at this point the periosteum of the meatus is seen to become continuous with the radiate fibrous lamina; this being cut through, the dermoid layer is seen passing down over the outer surface of the radiate fibres, and separating them from the epidermis. If the upper portion of this layer be drawn gently downwards by one hand, by means of a fine needle in the other, the delicate cellular tissue connecting it to the fibrous lamina can be broken up and it may be removed entire. The presence of the dermoid lamina may also be shown by the introduction of a fine bristle between it and the radiating fibrous layer, at the superior part of the *membrana tympani*, and then by passing it down the cellular tissue is lacerated.

In a healthy state, when uninjected by blood or by artificial means, the dermoid lamina is thin and transparent; examined by the microscope its structure is found to resemble areolar tissue. When injected, this membrane is observed to have numerous blood-vessels ramifying through it, and they form an elaborate plexus; when these vessels are enlarged, they give the red appearance to the surface of the *membrana tympani* which is so frequently met with during life. It is upon the supply of nerves to this membrane that the exquisite sensibility of the *membrana tympani* depends.

A knowledge of the existence of the membrane here described is of interest to the anatomist, who recognizes in it the secreting organ of the epidermoid layer of the *membrana tympani*; and to the surgeon, who by its presence is able to understand phenomena occurring in certain diseases of the ear which have been hitherto incomprehensible to him. Figure 17 is illustrative of the structure of the *membrana tympani*,

and it shows that the six layers of which it is composed are continuous with adjacent tissues.

I may state in conclusion, that the opinion of the non-muscularity of the fibrous laminæ of the *membrana tympani* advanced in the above paper, has been confirmed by Dr. Harrison of Dublin, in his dissection of the *membrana tympani* of the Elephant; he says, "I see no evidence of the muscular structure of the membrana tympani, so accurately described by Sir Everard Home in the Philosophical Transactions, and mentioned by subsequent writers, who seem to have adopted his opinions rather than to have examined the organ for themselves*."

Explanation of figure 17, *showing the six Laminæ composing the Membrana Tympani.*

A vertical section from without inwards of the meatus externus, membrana tympani and cavitas tympani.

M. E. Section of the meatus externus.
C. T. Section of the cavitas tympani.
M. T. Section of the membrana tympani.
a. The epidermis lining the meatus externus.
b. The dermoid layer of the meatus externus.
c. The periosteum of the meatus externus.
d. The periosteum of the tympanic cavity.
e. The mucous membrane of the tympanic cavity.
f. The epithelium of the tympanic cavity.
g. The circular fibro-cartilage of the membrana tympani.

* Anatomical Observations on some Parts of the Elephant, by Robert Harrison, M.D., Professor of Anatomy, Trinity College, Dublin. Proceedings of the Royal Irish Society, vol. iii.

IX. *On the Impregnation of the Ovum in the Amphibia.* (*First Series.*)

By GEORGE NEWPORT, *F.R.S., F.L.S.* &c.

Received June 20,—Read June 20, 1850.

THE communication which I have now the honour to present to the Royal Society is a portion of a series of investigations on the Development of the Embryo on which I have been for some years engaged, and which was commenced in a paper on the Development of the Myriapoda, that was honoured with a place in the Philosophical Transactions for 1841. I now propose to give the results of my observations on the Amphibia, reserving to a future early occasion the continuation of those on the Invertebrata commenced in the paper alluded to.

The Amphibia, of all the vertebrated animals, afford to us the readiest means of investigating the difficult subject of Impregnation by actual experiment, and it is only, perhaps, by combining experiment with careful observations on the physical conditions that affect the development of the germ, and comparing these with the facts of the natural history and instincts of the species, that we may hope, ultimately, to obtain some further insight into this one of Nature's most hidden secrets.

I shall endeavour, therefore, in this communication, to show the condition of the ovum in the Amphibia through its earliest changes, and also before and immediately after impregnation, and to detail experiments made with a view to learn by what means its fecundation is effected;—and in a future communication I propose to trace the development of the embryo from the time of fecundation to that of its liberation from the ovum, in the two chief divisions of the class,—the tailless and the tailed Amphibia. The subjects thus naturally form two series—Impregnation and Development.

IMPREGNATION OF THE OVUM.

The history of what we can now prove to be the agent of impregnation, the spermatozoon, deserves to be especially noticed. Although great attention has been paid by physiologists during the last thirty years to almost every point of inquiry connected with the production and physical composition of the seminal fluid of animals, and its relation to the fecundation of the ovum, we have remained to the present time without any acknowledged proof either of the part which the different constituents of this fluid take in impregnation, or of the mode in which it effects impregnation. This perhaps is little to be wondered at when we remember how many years elapsed before the great discovery of HAM and LEEWENHOEK of the existence of moving bodies in the fluid, as part of its normal composition, was admitted. It is now one hundred and eighty-three years since LEEWENHOEK communicated the important discovery

of these bodies to the Royal Society*, and regarded them as in some way essential to the fecundation of the ova; although his conjecture that they became the future embryos was erroneous. Eighty-five years afterwards, Dr. Parsons, Foreign Secretary of the Royal Society, believed it to be "extreme nonsense to imagine that the insignificant animals called *spermatic animals* can contribute anything towards propagation," &c.†, and it was not until the publication of the observations of Ledermüller‡, a few years after that, that the production of spermatozoa, as part of the fluid, began to be admitted. Dr. Hill, in the notes to his English translation of Swammerdam's Biblia Naturæ§, two years later, mentioned them as abundant in the Frog at the season of pairing, but that it was then the fashion to doubt even their existence. Yet Needham, ten years after this, while acknowledging that these bodies are found in the fluid of all animals, adopting the views of Buffon and Daubenton, stated that they do not exist until after the fluid is removed from the vessels, and decomposition has commenced‖. And later still, even in our own time, their existence has been denied in the most positive manner by Sir Everard Home¶. Spallanzani, however, was so well acquainted with them, as found in the Frog and Toad, that he has recorded his great surprise at not observing them in the latter on two occasions**. Bonnet†† and Gleichen‡‡, also, well knew them to abound in the males of animals of distinct species at the season of impregnation, but discovered that they are usually absent in hybrids, a fact that has since been confirmed by Prevost and Dumas§§. These two observers, regarding the spermatic bodies, with Leewenhoek, as essential elements of the semen, believed that they actually penetrate bodily into the ovum, and become by metamorphosis part of the future embryo. Still more recently it has been stated by Dr. Barry‖‖ to this Society that he has actually seen the spermatozoon within the ovum, a statement which my own observations do not enable me to confirm.

Before any satisfactory conclusion could be arrived at respecting the importance of the spermatic bodies in impregnation, it was necessary to ascertain their nature, to trace their mode of development and production, to establish the periods of their occurrence in different classes of animals, and to learn something of their chemical

* Philosophical Transactions, 1667, vol. xii. p. 1040.

† Philosophical Observations on the Analogy between the Propagation of Animals and that of Vegetables. 8vo. 1752 (note), p. 44.

‡ Physikalische Beobachtungen der Samenthierchen. Nuremb. 1756. And also, "Beyträge zu denen Beobachtungen derer Saamenthiergen und Kleiste Aale gehörig. 12mo. Frankfurt und Leipzig, 1759."

§ Book of Nature, folio, part 2 (note), p. 105, 1758.

‖ Notes des Nouvelles Recherches sur les Découvertes Microscopiques de l'Abbé Spallanzani par M. Needham. Lond. 1769, tom. i. p. 196.

¶ Lectures on Comparative Anatomy, 4to, vol. v. pp. 332 and 337. 1828.

** Dissertations relative to the Natural History of Animals and Vegetables. Lond. 1789, p. 151.

†† "Contemplations de la Nature;" and "Œuvres d'Histoire Naturelle," 4to, tom. iii. p. 454, &c. 1779.

‡‡ Abhandlung über der Samen- und Infusionsthierchen. Nuremb. 1788.

§§ Annales des Sciences Naturelles (Prem. Série), tom. i. p. 182, 1824.

‖‖ Proceedings of the Royal Society, vol. iv. p. 432. Phil. Trans. part 1, 1843, p. 33.

composition, as well also as of the fluid portion of the semen in which they move. Most of these inquiries have been well followed out by WAGNER, SIEBOLD, MULLER, and more especially KÖLLIKER, and more recently by WAGNER and LEUCKARDT, from whose labours we have now some positive information which enables us to deduce a fair conclusion respecting their function, although a direct proof of its correctness is still to be supplied. Most observers now believe with KÖLLIKER that the spermatozoa (still so called) are not independent living organisms, but are merely elementary constituent parts of the male body, an opinion in which my own investigations lead me fully to coincide. This opinion, indeed, is not entirely new, as a like view was held by some observers at the beginning of the last century, when it was still questioned whether the spermatozoa are normal constituents of the semen. Dr. DRAKE*, in his "New System of Anatomy," while acknowledging that he had seen the seminal animalcules, and combating on the one hand the theory of LEEWENHOEK respecting them, and on the other the view that had previously been held with regard to the ovum, doubted their separate organization, and suggested that they "may be nothing more than some large particles of mixed fluid, whose motions and different figure the microscope discovers to our eyes," &c. G. TREVIRANUS† more recently held a similar opinion, that they are not independent animals, but are analogous in their structure and properties to particles in the pollen of plants, and that their motion is of the kind discovered by ROBERT BROWN in vegetables. KÖLLIKER‡, however, first distinctly referred them to a class of known organic constituents of the living body, the vibratile cilia, a view which had previously been discussed and inclined to by MÜLLER§.

But however much our knowledge has become settled in regard to the nature of the spermatic bodies themselves, and their mode of development, their relation to the fluid portion of the semen in which they are contained is still a matter of doubt. H. GOODSIR‖ regards certain albuminous flakes in the fluid portions of the semen of Crustacea as the debris of dissolved cells, and as the source of nourishment and development of the spermatozoa; while a more recent observer, Dr. KIRKES¶, regards the spermatozoa as the elaborators of the fluid, and the conveyers of it to the ovum at the time of impregnation. This latter supposition was originally advocated by WAGNER, VALENTINE and BISCHOFF. But two of these observers have recently changed their views**, and now regard the fluid portion as only of secondary importance in impregnation, and the spermatic bodies as of essential. This view, as WAGNER states††, is founded chiefly on the fact that in some of the invertebrata the whole mass

* New System of Anatomy, by JAMES DRAKE, M.D., F.R.S. vol. i. p. 352, 1707.

† TIEDEMANN, Zeitschrift, vol. v. part 2, 1835.

‡ Beiträge zur Kenntniss der Geschlechtsverhältnisse und der Samen-flussigkeit wirbelloser Thiere. Berlin, 1841.

§ Elements of Physiology (Eng. ed.), part 6, 1841, p. 1478.

‖ Anatomical and Pathological Researches, 1844, p. 40. ¶ Handbook of Physiology, 1848, p. 610.

** BISCHOFF in MÜLLER's Archiv, 1847. WAGNER in Article "Semen," Cyclopædia of Anatomy and Physiology, part xxxvi. January 1849. †† *Loc. cit.* p. 507.

of the semen appears to be constituted almost or entirely of spermatozoa, while scarcely any *liquor seminis* can be detected;—and further, on the great improbability, perhaps impossibility, of the liquor seminis of those animals which expel their ova into water before impregnation being brought into contact with the ovum. But the same author justly remarks, that "even up to the present day this hypothesis of the influence of the liquor seminis has not met with any direct refutation." To this I may add, that however strong the presumption may be in favour of the agency of the spermatozoa in those instances in which a liquor seminis has not been observed, it affords no sufficient reason for disbelieving that the spermatozoa are not resolved into fluid at the moment of fecundation; or that in those animals in which the liquor seminis occurs in abundance it is not that which impregnates the ovum.

The question then, so far as *proof* is concerned, both of the direct agency of the spermatozoa, and of the non-efficiency of the liquor seminis in impregnation, remains open, as well also as that which involves the knowledge as to how impregnation is effected.

It is to these questions that this communication which I have now the honour of laying before the Royal Society is chiefly directed. I propose *first* to show the time and mode of disappearance of the germinal vesicle, and the condition of the ovum in the Frog and Newt, immediately before and after impregnation, and to endeavour to supply proof from actual experiments that the spermatozoa alone, in all cases of communion of the sexes, are the sole agents in impregnating the ovum; and further, that impregnation *cannot* be effected by the *liquor seminis*; and next to examine in what way the agency of the spermatozoa is influenced, impeded, or exerted.

1. CHANGES IN THE OVUM WITHIN THE BODY.

The ovum of the Amphibia has so frequently been the subject of examination by the best observers that a further detailed account of its development may at first appear to be useless, after what we already know of its changes through the labours of Swammerdam, Leewenhoek, Roesel, Spallanzani, Prevost and Dumas, Rusconi, Baer, Reichert, Vogt, Bell and others. But apart from the fact already mentioned, that the ovum of the Amphibia affords us the best means of actual experiment on impregnation, there are questions which relate to its earlier conditions on which the observers named are not agreed, but which are of importance with regard to the physiology of reproduction in the whole of the vertebrata.

I shall state, therefore, what I have myself observed with regard to these questions from the time when the ovarian ovum is approaching to maturity to that of its expulsion from the body, before entering on the subject of its impregnation.

As our means of comparing and testing the accuracy of all observations in natural history, and of experimental results in physiology, depend mainly on the correct identification of the objects examined, I may here state at once that the objects of the following details have been the Frog, *Rana temporaria*, and the Toad, *Bufo vul-*

garis, among the *Anoura*; and the *Triton palustris*, *Lissotriton punctatus* and *L. palmipes*, among the Water Newts, the *Urodela*. Neither Spallanzani, Prevost and Dumas, nor Rusconi, to whose observations I shall have frequent occasion to refer, mention the species they have examined. Spallanzani has given only the popular names of his animals, but Rusconi has given a figure of his, which appears to have been *Rana esculenta*, and as the description he has given of the ovum of this species agrees with the description given by Prevost and Dumas, it is probable that the species they employed was the same.

The Ovarium Ovum.—When the frog, *Rana temporaria*, is examined in the autumn, after it has ceased to feed, and is preparing to retire to its winter quarters, the ova within it have already attained to more than two-thirds of their ultimate dimensions before leaving the ovaries, and have begun to distend the abdomen. They remain in this state through the greater part of the winter, while the frog is hybernating, as Professor Bell remarks*, in the mud at the bottom of ponds and stagnant waters. But as the spring approaches, and the animal is aroused from its lethargy by increased temperature, the ova then rapidly acquire their full development. A female frog, taken at the end of September, with her body enlarged with ova, was confined in water in a cold room, undisturbed through the winter, excepting only at intervals of examination. The weather being mild, and the temperature of the room during October and November being sometimes at or but little below 50° Fahr., the frog remained active, and came frequently to the surface to respire. In December the temperature sunk to below 40° Fahr., when the frog became lethargic, and scarcely changed its place at the bottom of the water during nearly a fortnight, while the temperature was almost stationary, and ranged only from 35° Fahr. to 37° Fahr. On the 10th of January, when it had again risen to 40° Fahr., and that of the water to 37°·5 Fahr., the animal was still submerged and motionless; but on sudden exposure to the light of a candle it crept languidly, and almost imperceptibly, to a distance of about two inches, and again became quiet. On the 26th of January the temperature of the room had risen gradually and continuously to 52° Fahr., and that of the water to 48° Fahr., but the frog remained submerged and perfectly quiet with its eyes partially closed. Although it was not cognizant of any object by sight, the irritability of its body was now much increased, as it moved instantly when touched ever so lightly, but quickly relapsed into its previous state of rest. On the morning of the 1st of February, the temperature being then 48° Fahr., it was still submerged and motionless, but in the evening, when the warmth was increased to 52° Fahr., I found it with its nostrils only above the surface of the water, and evidently beginning to respire freely, but its eyes were completely closed. When the light of a candle was suddenly cast upon it, the eyes were slowly opened, but its body remained immoveable. On the following day, February 2, it was evident that its hybernation had been brought to a close, as it was then active, with its head out of the water, and its eyes widely open,

* History of British Reptiles, 1832, p. 89.

and perfectly alive to external objects, as when the hand was slowly approached it withdrew beneath the water. The temperature at this time was 53° Fahr. During this period of hybernation the frog became slightly emaciated, and its abdomen, instead of being more enlarged, was somewhat diminished in bulk,—a good proof that during the inactivity of the respiratory and circulatory functions, the secretory also are lessened, and the development of the ova is arrested. But although no food was supplied to the frog at this time, and none probably is taken by the creature in its natural haunts, as at the time it comes forth but few of the objects on which it feeds are abroad, its body soon became enlarged, showing that the ova were then rapidly attaining their full development. Between the 2nd and 22nd of February the temperature of the room was occasionally as low as 42° Fahr., yet the creature remained active beneath the water, without relapsing into its previous state of hybernation. It only continued longer beneath the surface without rising to respire. At this period, having found that some frogs in their natural haunts had already come forth, I removed the subject of these observations also from the water to a damp locality, and on the following day found it greatly changed in appearance. While confined in the water it was of a dull dirty brown colour, but some hours after its removal it cast its tegument, and changed to a bright yellow, with the usual brown markings, and had increased in size, both in its body and limbs.

The conclusion to which these circumstances seemed to lead was, that quickly after the frog leaves its hybernaculum, it casts its tegument as the insect escapes from its puparium, and acquires new vigour, while the ova are attaining their full growth. The Toad undergoes a similar change. About a fortnight later in the season than the Frog, I have seen many toads in a shallow ditch of slow moving water in the act of casting their dark brown tegument, and acquiring one of a greenish yellow.

On examining several frogs taken from their natural haunts, I found them in, as nearly as posible, the same state of development with regard to the ova, judging from external appearance, as the specimen I had watched through the winter. A few had just paired, but the majority were still single. On opening the bodies of the latter, I found the ovaries greatly enlarged, and the ova apparently ripe, but still contained in the ovisacs.

It is at this period, therefore, immediately after hybernation, and before the ova have left the ovaries, that the condition of the ovum is a matter of great interest with reference to the structure and contents of the germinal vesicle, the period at which the vesicle is changed or disappears, and the circumstances under which the ovum escapes from the ovary, and is received into the oviduct.

The Germinal Vesicle.—The fate of the germinal vesicle in the matured ovum is still a matter of doubt. Previous to the embryological researches of Dr. Martin Barry, it was usually believed that the vesicle entirely disappears before or at the time of fecundation of the ovum. But this view was combated by the author named, who, quoting the opinions of previous inquirers, contended that the germinal vesicle in

Mammalia does not disappear, as believed by PURKINJE*, in Birds and Amphibia, by bursting during the generative act, and pouring its contents into the germinal layer of the fecundated ovum. Neither, as supposed by BAER†, by being urged forwards and burst between the vitellus and its membrane before fecundation. Nor, as stated by RATHKE‡, with reference to the Crustacea, by disappearing while still within the ovary. Or, as supposed by WHARTON JONES§, in Birds and Amphibia, by approaching the surface of the yelk, and by the giving way of the coats of the vesicle, and the effusion of its contents on the surrounding surface of the yelk. Or, further, as believed by BISCHOFF‖, by disappearing at the time of exit of the ovum from the ovary. On the contrary, Dr. BARRY has stated that the germinal vesicle returns to the centre of the ovum, and the germinal spot to the centre of the vesicle, before the ovum leaves the ovary, and that these do not become dissolved, but only are changed in character by a process of cell development within them, which ends in the production of two cells in the centre of the yelk, which are the foundation of the body of the future embryo.

Perhaps what I am about to mention may assist us to reconcile or correct the views of this embryologist, as well as those of the authorities he has quoted. It is well known that if the ovum of the Frog is examined before the yelk has attained to one-half of its ultimate dimensions, the germinal vesicle is distinctly visible as a large circular body near the centre of the yelk, apparently granular in its interior, and more opake than the yelk itself. In the centre of the vesicle its nucleus, the germinal spot, is then equally distinct. If the ovum is examined when it has nearly acquired its full dimensions, the vesicle is still found to exist, but, as compared with the size of the entire ovum, is relatively smaller than at earlier periods, and is recognized with more difficulty, owing chiefly to the yelk cells having both increased in number around it, and also acquired a darker colour. It is equally well known that all appearance of the vesicle is lost in the Amphibia, as in Birds, before the ovum is prepared for fecundation; but as to the way in which it disappears, observers are not agreed, or even as to the time.

Structure of the Germinal Vesicle.—Having collected a number of frogs that had recently left their hybernacula, and had not yet paired, I placed some in spirit for examination. On dissecting them afterwards, I found that in some the ova had nearly reached maturity, but had not left the ovary (Plate XIV. fig. 2 *p*). The yelks being rendered firm by the spirit, I was able, by gentle pressure, to break open some of these beneath the microscope, without diffluence of the contents. The aggregated yelk cells were then seen to consist of two kinds; the one dark-coloured, which form

* Symbolæ ad Ovi Avium Historiam ante Incubationem, 1825; and Article "Ei," Encyclop. Wörterbuch, Band x. p. 112, 1834.

† "Lettre sur la Formation de l'Œuf," in Breschet. Repertorium, 1829.

‡ Untersuchungen ueber die Bildung und Entwickelung des Fluss Krebses, fol. Leipzig, 1829.

§ Philosophical Transactions, 1837, part 2. ‖ R. WAGNER's Lehrbuch, &c., 1839.

the upper portion of the yelk, and which diminish in intensity of colour from brown or black at the circumference to a leaden or grey in the centre; the other, which forms the inferior portion, consisting of cells that become lighter-coloured as they approach the surface. The whole form a mass of nucleated cells of nearly uniform size, closely aggregated together. In the interior of the yelk, amidst the dark-coloured cells, and *much more near the surface of the dark* than that of the white portion of the ovum, I was surprised to find the germinal vesicle still entire (fig. 6), and of a somewhat oval, lenticular form, although irregularly compressed by the contraction of the whole egg in the spirit. It was of a dense white colour, and opake, from the action of the spirit, and was in striking contrast to the dark cells of the yelk, which adhered to its surface, and amidst which it lay imbedded like the kernel in a peach or apricot. On the surface of the black portion of the yelk was a minute orifice, already noticed by Prevost and Dumas*, the outlet of a canal that passes through this portion of the yelk to the germinal vesicle in its interior (fig. 6). This I believe to be the result of the yelk cells having only imperfectly closed around the germinal vesicle. It is however of some consequence in the future development of the ovum, as it is in this canal that the cleavage of the yelk is commenced. The vitelline membrane was already formed, but I could not discover any orifice or perforation in it, either corresponding to the canal in the yelk, or to any other part of the surface. It is not possible to mistake the germinal vesicle for any portion of the lighter substance of the yelk,—first, from the fact that the vesicle at this period is of an intense, opake, white colour, very different from that of the yelk substance,—next, from its being completely isolated from the lighter, and imbedded in the dark substance,—and lastly, from its being still invested with a distinct envelope. On removing the vesicle, and examining it separately, first, as taken from the yelk, without crushing it, and next by gentle compression, and with the highest powers of the microscope, the interior was seen to be filled with secondary cells. Each of these, formed by a distinct envelope, *appeared* to contain other, or tertiary cells, and strongly reminded me of the developmental cells of the spermatozoa in the male organs, since these again seemed to contain granules, or quaternary cells. In the midst of the secondary cells I was able to distinguish, in the centre of the germinal vesicle, in some specimens, one or two cells of larger size than the rest, and which I regarded as the remains of the germinal spot, or central nucleus. In those ova which, from their size and general appearance, seemed to be the most mature, the peripheral series of cells within the germinal vesicle were of smaller diameter than those nearer to the centre, as if the earlier developed secondary cells had disappeared and liberated their contents. The cells of the dark portion of the yelk that adhered to the germinal vesicle were also nucleated, but were of much smaller size than the peripheral cells of this body. I must remark, however, that saving the fact noticed, of having seen in some vesicles one or two cells near the centre of larger size than the rest, I have not been

* *Loc. cit.* tom. ii. p. 104.

able to distinguish any separate nucleus, or germinal spot, which seems, at this time, to have disappeared as a distinct body. The germinal vesicle thus near its maturity is a mother-cell that contains a multitude of daughter or secondary cells, each, apparently, including its own progeny.

It is thus certain that the germinal vesicle exists in the ovum of the Frog until after the period of hybernation. But in individuals that have been several days abroad, and in which the ova are so far matured as greatly to distend the body, and be nearly ready to leave the ovisacs, I have not always been able to detect the vesicle. The yelk has then a greater proportion of white substance in its interior, intermingled with the dark, and this, I suspect, is the result of the disappearance of the vesicle.

In the ovum of the *Toad*, when as nearly mature as that of the Frog before leaving the ovisacs, I have been unable to detect any trace of the germinal vesicle. The dark portion of the yelk is then quite distinct from the light, and forms a cortical stratum of intensely black pigment, scarcely more than one-sixth of the diameter of the yelk in thickness. The light portion is of a yellowish white, and from which the germinal vesicle, when present, is not readily distinguished. But at a little earlier period, although only a few days before the pairing of the Toad, I have found the vesicle fully as large and as distinct as before its disappearance in the egg of the Frog, but situated more distant from the centre, and nearer to the black, the future dorsal surface of the egg.

In the great Water Newt, *Triton palustris*, the yelk of the matured ovarian ovum is of a dull pea-green colour, which in spirit is changed to a greenish yellow. On breaking open the yelk of this species, after it has been hardened in spirit, I have always found the germinal vesicle of the same opake, intense white colour, of precisely the same structure, and situated in the same part of the yelk as in the Frog. It has also a canal passing from the middle of the surface of the darker-coloured portion of the yelk, through its substance to the vesicle, as in the Frog.

In the lesser Newts, *Lissotriton punctatus* and *L. palmipes*, the yelk is of a brown or liver colour on the future dorsal surface, with a white central spot, and of a white or pale straw colour on the ventral. In ripe ovarian ova of these species also I have found the germinal vesicle of the same white colour, and having the same structure as in the larger Triton and the Frog.

In each of these instances, not merely when the ovum is immature, but even when nearly ready to leave the ovisac, the germinal vesicle is situated in the interior of the yelk (fig. 6), and not immediately at the surface, and thus far the fact is in accordance with the observation of Dr. Barry, that in the Mammalia the germinal vesicle is in the interior of the ovarian ovum, and does not disappear on the surface. But, nevertheless, it is not in the *centre* of the yelk, its place, as I have stated, is *excentric*.

Time of disappearance of the Vesicle.—It is well known that in frogs and toads the ovum is never impregnated until after it has left the body, and consequently not until long after it has left the ovary, and the germinal vesicle has entirely disappeared.

This disappearance does not, I think, take place at the instant the ovum is about to leave the ovisac, but a short time before; as I have found the ova of the Frog in one instance more matured than in that already described, still contained in the ovisacs, and yet most of them without any remains of the vesicle which I could identify as such, and with the yelks containing a larger proportion of white substance, as in the Toad. In a very few, however, the vesicle was still present, and exhibited the structure I have described. Certainly, then, the vesicle is not burst at the moment the egg escapes from the ovisac. There seems to be a short period of time between the disappearance of the vesicle and the full maturity of the ovum, during which the yelk itself undergoes some further change, and acquires the appearance noticed in the matured eggs of the Toad, and in the most advanced of those of the Frog. No trace of the germinal vesicle can be detected in any ova that have left the ovary and are contained in the cavity of the abdomen, before entering the oviducts. I have examined many ova, both of the Frog and Newt, from the abdominal cavity, but in every instance the vesicle has entirely disappeared. In some specimens, which seemed to have been in the act of escaping from the ovary when the animal was killed by immersion in spirit, I have found in the place occupied by the vesicle an aggregation of white nucleated cells, which, examined by the microscope, exhibited a close resemblance to those seen in the interior of the vesicle. In the midst of these there has occasionally been one or two of larger size than the rest, and which I have imagined to be the remains of the germinal spot, and possibly the origin of the future embryo vesicle of the impregnated ovum, an opinion, however, which I have not had the means of verifying, and I must further state that I have failed to recognize these larger cells in ova that were free in the cavity of the abdomen. Each of the three species of Newt, as well as the Frog, have presented similar appearances in the germinal vesicle and ovum under similar circumstances.

Thus it is quite certain that the germinal vesicle disappears in the Amphibia before the ovum enters the oviduct. I believe it does so in the interior of the yelk, not in the centre, but nearer to the dorsal than to the future ventral or white surface; and not, as has been supposed, on the dorsal or dark surface, between the vitellus and the vitelline membrane. This view is supported by the fact, that that portion of the yelk which incloses the vesicle in an advanced stage of the ovum in the Frog is of a more or less intense black colour, while the vesicle is perfectly white; and that at a further advanced stage, after the vesicle has disappeared, and its place is occupied by a collection of white cells, the dark portion of the yelk still preserves its intense black colour, except at the point that corresponds to the central canal, which then has a leaden hue. Prevost and Dumas*, and also Rusconi†, have mentioned that there is a yellow spot at a corresponding part of the dark surface of the egg of the species they have examined after impregnation, *Rana esculenta*?, but these appearances must

* Annales des Sciences Naturelles, tom. ii. p. 104.

† Développement de la Grenouille Commune, 4to. Milan, 1826. p. 9.

not be mistaken for the germinal vesicle arrived at the surface. There is a similar spot, and that too of an elevated form, on the egg of each of the *Lissotritons*. But independent of the fact that the germinal vesicle has entirely disappeared from the interior of the egg before it escapes from the ovary, this spot is shown not to be the vesicle, both in the fact that in the egg of *Rana temporaria* the dark portion of the yelk is unchanged, while in each case the spot is perforated, and leads into the canal that passed originally to the vesicle. I regard the spot as simply a protrusion outwards of the edges of the canal while closing, after the vesicle has disappeared. I shall presently show that a similar white spot is formed on the under surface of the egg of the Frog soon after deposition, and which might equally well be mistaken for the germinal vesicle.

Mode of disappearance of the Vesicle.—The mode in which the vesicle disappears may be inferred from the facts of its structure. Being filled with a progeny of cells which we may regard as of different periods of growth, and these again containing others, it is fair to conclude that this process of cell formation is that by which the parent vesicle is ultimately destroyed. At the time when the germinal vesicle has nearly attained its full size, the peripheral cells are smaller than those nearer to its centre, while the yelk cells that surround the vesicle are still smaller than either, and are of a dark colour. When, therefore, the vesicle has acquired its full size, by the simple vegetative endogenous growth of the contained cells, we may fairly presume that the death of the parent mother-cell, or germinal vesicle, takes place as the result of their enlargement, by the diffluence of its investing membrane; and the enclosed daughter cells, thus gradually set free in the midst of those of the yelk, as in the ideal (fig. 7), form one mass with the latter, and the moment of the actual disappearance of the vesicle thus escapes direct observation, its previous existence being indicated only by the unbroken outline of the investing membrane.

These views lead me to agree with Wagner and Barry in regard to the structure and mode of growth of the germinal vesicle, but not as to that by which it disappears. Dr. Barry indeed believes that the vesicle only becomes changed by its mode of development, and does not cease to exist. But most certainly it does disappear in the Amphibia, and, as I believe, through the growth of the young cells in its interior. I cannot therefore agree with Dr. Barry that the changes in the vesicle end in the production of two cells in the centre of the yelk, that give immediate origin to the embryo; but rather believe that it is from one of the central cells of the germinal vesicle that the future *embryo vesicle* takes its origin, while the remainder of the liberated cells are distributed with this through the substance of the yelk, when the segmentation of this body takes place. This opinion is in accordance with that of Vogt*, who found that in the ova of *Alytes obstetricans* the germinal spots increase in number, and that a few hours after fecundation small vesicles, similar to these spots, are scattered through the yelk. I have myself found similar vesicles in the fecundated egg

* Untersuchungen über die Entwicklungsgeschichte der Geburtshelfer-Kræte (*Alytes obstetricans*), 4to, 1842.

of the Frog about three hours after impregnation (fig. 10 *a*), but have not traced them to their origin. With regard to the disappearance of the spot in the germinal vesicle, the facts observed in the ova of the Frog agree with those noticed by Kölliker* in the ova of intestinal worms, that all appearance of the spot is lost before that of the vesicle. This circumstance, however, may be owing either to the spot having given origin to cells in the vesicle which quickly attain to similar dimensions, and from which it is not otherwise distinguished; or to its becoming entirely obscured by their multiplication. Although no observations have been made on the origin of the embryo vesicle that appears in the yelk after the disappearance of the germinal, I am still inclined to regard this as being in some way derived from the lost germinal spot, notwithstanding that Kölliker found a certain period of time elapse between the disappearance of the vesicle and that at which he was able to recognize this body.

Transit of the Ovum.—Thus, then, when the ovum escapes from the ovisac and ovary into the cavity of the abdomen, the germinal vesicle and spot have entirely disappeared, and it consists only of the yelk enclosed in an exceedingly delicate, structureless, vitelline membrane. This is its condition in the Frog, Toad and Newts. It is then extremely delicate and easily lacerated. The mode in which the ovum passes into the oviduct has been the subject of much inquiry. I am quite certain, as Swammerdam long ago showed, that the ova, when mature, pass from the ovaries into the cavity of the abdomen, and from thence into the oviducts, in the Frogs, Toads and Newts, quite independent of any intercourse with the male, as I have myself recently had an opportunity of proving. The frog I have already mentioned (p. 173.) as having watched through its season of hybernation, was kept apart from all others until the 2nd of April, at which time she had not deposited any ova. But from the altered form of her body it was evident that the ova had passed, or were at that time in the act of passing, into the oviducts. I then placed her in a vessel with others, some of which were males, but not one of these joined with her. Nevertheless, on the 6th of April she cast her ova, without having paired, and died on the following day. On examination after death, I found that the whole of the ova had left the ovaries, all of which, excepting only two still free in the cavity of the abdomen, had passed through the oviducts without any intercourse with the male. These ova of course were sterile, but it was worthy of note that their envelopes did not expand to so great an extent as those of the eggs of paired individuals.

Passage into the Oviduct.—In what way the ova pass from the cavity of the abdomen into the mouth of the duct has never been satisfactorily explained. Swammerdam examined the question with much care†, but was unable to form any decided opinion respecting it, as he correctly states that the mouths of the ducts are at a distance from the ovaries, and are not free to grasp the ova like the fimbriated extremities of the Fallopian tubes in Mammalia, but are confined in the peritonæum, which is continuous with that which passes over the pericardium and heart. Prevost and Dumas

* Müller's Archiv, 1843.

† Book of Nature, part 2, pp. 108, 109.

have since stated* that the ova after leaving the ovaries are seized by the tubes ("sont saisis par des trompes"), but they do not show in what way this seizure is effected. They have omitted to describe the structure of the parts concerned in the act, and have not mentioned the way in which the ova are conveyed to the tubes from the ovaries, or whether the mouths of the tubes approach the ovaries, as in Mammalia.

The entrance to the tubes in the Frog, as SWAMMERDAM has correctly shown, is in the peritonæum (Pl. XIV. fig. 1 *b*) at each side of the heart (*a*), and I have found it in nearly the same place in the Newts. The apex of the pericardium in the Frog is attached to the cartilage of the sternum by two layers of peritonæum, which together form the mediastinum, and enclose between them the trunk of the median abdominal vein, a branch of the vena cava. Tracing one of these layers of peritonæum upwards and over the pericardium, we find in it an orifice (fig. 1. and 2 *b*), at the part where it is reflected on itself to form the lateral portion of the suspensory ligament (*e*) of the liver (*c*). This orifice (*b*) is elongated, oval and funnel-shaped, and, when dilated, forms a kind of pouch at the anterior boundary of the space or cavity between the liver (*c*) and the heart (*a*), and laterally it is in free communication beneath the suspensory ligament with the common cavity of the abdomen. The oviduct (*g*) commences in this dilated orifice as a narrow tube with thick muscular parietes and with a thick mucous lining. It passes at first upwards and forwards, confined to the peritonæum, and then outwards above the base of the lung (*f*), gradually increasing in its dimensions. Immediately after it has passed the lung it becomes more enlarged, and as it passes backwards to the side of the spine forms many convolutions, which end in the dilated oviduct (fig. 1. and 4 *h*) or common receptacle for the eggs ready to be deposited.

The commencement of the oviduct in the Newts is very similar to that of the Frog. In the *Triton palustris* it differs only in the entrance being larger, and situated more to the side of the body, and above the lung, to the base of which, as well as to the peritonæal investment of the heart, it is confined, as in the Frog; but it has a more free communication laterally with the common cavity of the abdomen than in that animal.

The ova escape from the ovaries into the cavity of the abdomen among the viscera both in the Frogs and Newts, and are carried forwards to the spaces between the liver and heart on each side to the dilated mouth of the oviduct. They certainly are not seized by the tubes as they escape from the ovaries, as they are constantly found free in the abdominal cavity, while the mouths of the tubes being confined in the peritonæum, and having no appendages, cannot be extended to reach them. Their transfer seems to be effected in the Frog in part by the action of the abdominal muscles forcing them onwards in the spaces between the viscera, aided perhaps by the peristaltic action of the stomach and intestines; and their entrance into the tubes, when arrived in the vicinity, seems to be induced by an ingurgitory or suction action at the mouth, occasioned by the alternating and pulsatory motion of the heart, with which the tube is

* *Loc. cit.* tom. ii. p. 105.

connected by means of the peritonæum. The tube itself is formed of strong longitudinal and transverse fibres, which are continued into the peritonæum, and the former especially into the suspensory ligament, the free external margin of which bounds the outer side of the orifice. The transverse fibres are strongly marked at the commencement of the orifice, where there is a slight pouch; so that when the eggs are entering, these fibres doubtless prevent their return and transfer them onwards. This, I believe, is the way in which the eggs enter the oviducts. It is quite certain from the anatomy of the parts that they cannot be grasped by the oviducts until they are conveyed to them. I have not actually witnessed the passing of the eggs from the abdomen into the ducts in the Frog, but I have seen the eggs moved onwards in the smaller Newt, *Lissotriton palmipes*. Having deprived a female of this species of sensation and power of motion by division of the spinal cord through the medulla oblongata, I proceeded to open the abdomen to obtain ova from the oviducts for experiments on artificial impregnation. I then found that a number of ova were free in the abdominal cavity, and that some had very recently entered the ducts, while others were in the immediate vicinity of the mouths. The heart was still pulsating vigorously and with great regularity, and I then saw that at each pulsatory action the ova passed slowly forward between the liver and lung, towards the mouth of the oviduct, which still contained two or three ova that appeared to have entered at the moment of the operation. I did not witness the actual entrance of an ovum, but saw that the action of the heart certainly had the effect of inducing the advance of it to the mouth of the tube, and quite sufficient to lead me to regard this as one of the chief means of its entrance into the duct.

It is not until the ovum has become clothed in the oviduct with its gelatinous envelope that it is susceptible of impregnation. This remark applies equally to the Frogs, Toads and Newts. The ova of the Frog and Newt at large in the abdominal cavity are always entirely without this envelope, and consist simply of the yelk mass enclosed in an extremely delicate vitelline membrane. They are so easily injured that it is only with great difficulty that they can be removed from the abdomen for examination unbroken. Those of the Newt, when taken up ever so carefully by means of a hair pencil, often burst the membrane simply by their own weight. But immediately after they have entered the oviduct and begin to acquire their envelopes, the yelk appears to undergo some change, as it becomes much firmer and is less easily injured. Shortly after the egg has entered the duct, it gains the first layer of an investment, which, from the great similarity it bears to the gelatinous layer gained by the ovum of the Rabbit in the Fallopian tube, and regarded by its discoverer in that animal, Mr. Wharton Jones*, as the origin of the chorion, I am disposed, with him, to look upon as the analogue of that layer. This covering adheres very closely to the vitelline membrane, and is scarcely to be distinguished from it, except at certain periods of change. It is acquired before the egg has arrived at the first convolutions of the ovi-

* Phil. Trans. part 2, 1837.

duct. During the remainder of its passage the egg gains two other distinct layers of similar investment, which, together, we afterwards recognize as the gelatinous envelope of the Frog and Toad, and the capsule of the Newts. These envelopes are not merely simple means of protection to the egg during the production of the embryo, as has been supposed, but, as I shall presently show, are essential to it at the period of fecundation, and without which the egg is not susceptible of impregnation. The layer of envelope which I regard as the foundation of the *chorion*, is a dense, but very transparent thin covering, in immediate contact with the vitelline membrane, and is formed of cells so closely aggregated together as to have coalesced into a fibrous structure. The two layers external to this are also formed of cells, which, with their nuclei, are distinctly visible in the envelope of *Triton palustris*, in which they alternate in regular series. Although these layers, which constitute the jelly in the egg of the Frog, become detached in that of the Newts quickly after oviposition, and, expanding as in the Frog, they leave the egg at liberty in a chamber in their interior, they are nevertheless essential to the impregnation of the ovum, which takes place before or at the time of leaving the body, as in Frogs and Toads. Rusconi* removed the envelopes of the egg of frogs, and found that the embryo still became developed, and thence concluded that these coverings serve only mechanical purposes during the changes; but it will presently be seen that they have a more important function at a much earlier period. During the time they are in course of formation around the egg the yelk undergoes some further change. The light portion becomes of a whiter, and the dark portion of a deeper colour. Internally the cells vary more in size, the lighter-coloured being the largest. I have not succeeded in recognizing any embryo or central vesicle up to this period.

2. CHANGES AFTER SPAWNING AND IMPREGNATION.

First period of development.—It has been long known that a division or cleavage of the yelk of the Frog's egg is one of the earliest and apparently invariable results of fecundation. The primary division was first seen by Swammerdam, and was figured† and mentioned, but was not understood by him. Spallanzani long afterwards recognized it in the egg of the Toad (*Alytes obstetricans*‡), which he says becomes about a day after fecundation marked "with two furrows which meet to form an angle,"—that the furrows afterwards become deeper, and that "two small tumours arise on each side of the furrows,"—changes which have since been more accurately and completely described by Vogt§. Spallanzani also says that the egg of the common Toad is "marked with four furrows which intersect each other at right angles nearly like the husk of a chestnut half-opened," but he seems to have thought this was the usual condition of the ovum. To Prevost and Dumas‖, however, we owe the important

* Développement de la Grenouille commune. Milan, 1826.

† *Loc. cit.* tab. xlviii. figs. 5, 8.

‡ *Loc. cit.* vol. ii. p. 159.

§ Untersuchungen über die Entwicklungsgeschichte der Geburtshelfer-Kræte (*Alytes obstetricans*), 1842.

‖ Annales des Sc. Nat. tom. ii. p. 110, 1824.

discovery of the cleavage of the yelk as a process of the fecundated egg; to Rusconi*, Baer† and others, its full exemplification in the Amphibia; and to Barry‡ and Bischoff§ its detection and elucidation in the Mammalia.

The agent immediately concerned in these changes is believed to be the embryo vesicle and its progeny, produced after the disappearance of the germinal vesicle. But it is yet uncertain what is the origin of the embryo vesicle, or whether it exists in the unfecundated ovum. As cleavage of the yelk certainly is not the result of the disappearance of the germinal vesicle, which disappears from all ova of the Amphibia, whether they are afterwards impregnated or not, I was desirous, at the commencement of my experiments on impregnation, to learn *from direct observation* whether the unfecundated ovum ever passes through any stage of cleavage; since the ascertainment of the fact in the negative would be an important test in the experiments I was about to make. For this purpose it was necessary to collect many pairs of frogs at the proper season, and when from symptoms which are soon recognized, it was found they were about to cast their ova, to wait patiently, perhaps for many hours, for the result, in order that the exact condition of the ovum, impregnated naturally, should be first ascertained. Swammerdam long ago remarked that the spawning of the frog takes place very rapidly "by a single effort‖." It is often completed, as I have found in the English species, in a few seconds, and usually in less than a minute, during which the male impregnates them, so that if the animals are not closely watched the opportunity of observing the earliest appearances of the ovum is lost. Having noted the condition of the impregnated ova of several pairs of frogs within the first few minutes after spawning, I found those of different individuals vary much with respect to the white or inferior surface, and exhibit appearances that may readily be mistaken for the breaking up of a vesicle on the surface. This appearance is due to a more or less complete state of maturity of the eggs of different broods, and according as their spawning has been retarded or hastened. The peculiarities are the most marked in the least matured, the white surface of the egg being the last completed part, and forming the base of the egg in the ovisac (fig. 5). Having noticed the appearances of the eggs when impregnated naturally, I was enabled to compare them with others impregnated artificially, and these with some of the same brood not impregnated.

Immediately after the frog has spawned the ova form a close rounded mass, which at first is scarcely so large as a walnut. They then seem to consist almost entirely of dark-coloured yelks with thin gelatinous envelopes. The form of the egg is then somewhat oval, with the white portion a little more conical than the dark and differing slightly in different ova. In some there is a dark spot in the centre of the white, that looks like a depression or cavity, or perhaps a vesicle. I am not certain

* *Loc. cit.*

† Müller's Archiv, 1834.

‡ Philosophical Transactions, 1839, 1840.

§ Entwickelungsgeschichte des Kaninchen-eies, 1842.

‖ *Loc. cit.* part 2. p 111.

that this appearance is in reality a vesicle, and therefore am content to describe it as a spot, although it conveys the idea of being a vesicle. In some ova there are two, four or six of these spots imbedded each in a small portion of white substance. When only a single spot exists, the white surface of the egg for some space around it is more defined than afterwards, and exhibits faint indications of a crucial division of the yelk on this surface immediately around the spot. This is the condition of a few ova immediately after spawning; but the majority have then advanced farther in their changes, and show four or six rounded dark-coloured spots at a little distance in the place of the single central one. When four spots occur they are usually arranged in a quadrangle, and are less than their own diameter apart. They convey the idea of being derived from the central one; but I have never seen any division of this, and if such division takes place, I think it must occur before or at the very moment the ova are expelled. In a further advanced stage of the ovum the four dark spots have become larger, and are each imbedded in a distinct portion of the white surface.

One minute after deposition the spots are more widely separated, and are then each encircled by a separate patch of white substance. *Two minutes* after spawning six dark spots have made their appearance, one of which is situated nearly in the centre, and the remaining five are so arranged around this that the white patches in which they were imbedded seem to have coalesced. In *three minutes* the spots are further enlarged, and appear joined by a dark line of colour extending from each, so that the whole form, as it were, a knotted ring that includes a patch of the white surface of the yelk with one of the dark spots near the centre. In *four minutes* the ring around the included white substance is more distinct, and the white surface of the egg has increased in extent. In a further advanced stage at this period the white portion included in the ring exhibits the appearance of a white, very opake patch, the dark spot in the centre having disappeared. Around this opake white patch is the dark-coloured knotted ring, now become more uniform, and resembling a ragged chink or slight circular furrow or division in the white surface. The centre of this hemisphere of the egg thus comes to be occupied by a white patch instead of the dark spot. At *five minutes* this central white patch,—which, as before stated, and from what afterwards occurs, may readily be mistaken, on casual inspection, for the germinal vesicle, altered in its appearance and arrived at the surface,—were it not that we now know that this has long before entirely disappeared,—becomes more defined, and the dark circle around it is more uniform and distinct. At *ten minutes* the central patch is a little reduced in size, and the circle that incloses it begins to take the appearance of a diffused halo. At *fifteen minutes* the central white patch is more reduced, and the halo is spread wider, while the whole of this hemisphere of the egg has acquired a whiter appearance, and become more distinct from the dark colour of the sides and future dorsal hemisphere. At *twenty minutes* the central patch has become still smaller and rounder, and the dark halo much broader.

At this period an interesting circumstance occurs which may hereafter be found

to have some reference to changes in the interior of the yelk, possibly to some rapid evolution of the so-called central or embryo vesicle in the locality originally occupied by the germinal vesicle and spot, which, as we have seen, is nearest to the dark surface —it is the partial rotation of the entire yelk. Up to about this period the ova remain undisturbed in the water in a mass as they are expelled, and lie indiscriminately, some with the dark and some with the white portion of the yelk uppermost, or horizontal. But during the time that has passed since the ova have been in contact with water, the envelopes have imbibed fluid and expanded until these investments of the yelk have acquired a thickness equal to about two-thirds of the diameter of the yelk itself. The yelks that have remained to this time with their white surface uppermost now change their position spontaneously by a partial rotation of the whole mass of each on its axis, within the vitelline membrane, until the dark surface of the whole is placed uppermost. Whether this change of position is merely the result of an expansion of the vitelline membrane at this period, when the ovum is rapidly ceasing to be susceptible of impregnation, as I shall presently show is the case after this lapse of time in the water, or whether it be also connected, as we may fairly believe, with changes going on in the interior of the yelk, I am not prepared to decide. It is important, however, to note that the change takes place at about the time at which I have found a great abundance of bright clear rounded vesicles distributed throughout the yelk, but chiefly in the place originally occupied by the germinal vesicle. In some of these vesicles, which I regard as the progeny of the germinal vesicle, I have seen irregular-shaped nuclei that appeared to be formed of a multitude of nucleoli. These vesicles convey to me the same idea as those seen by Bischoff in mammalian ova, excepting only that in the egg of the Frog they contain compound nuclei.

At *thirty minutes* the central patch on the white surface of the egg has almost disappeared, and the halo around it is still more diffused. At *forty-five minutes* it has entirely disappeared in most specimens, and its place is occupied by a broad dark area which includes the boundary of the previous halo, and which appears to be occasioned by a slight depression in the centre of this surface of the yelk. *One hour* after spawning this depression is somewhat deeper. The white surface has become still more defined, and the dark has acquired a more intensely black colour. The egg remains in this state without further perceptible change during the succeeding *second* and *third hour*, excepting only that the depression in the white surface becomes a little deeper, but it has almost disappeared at the end of the *fourth* hour, when *segmentation* or cleavage of the yelk is about to take place. But this is not invariably the case. When it does remain it is always of an oval form, and the primary cleavage of the yelk, as it proceeds on either side from above downwards, meets in its centre and invariably passes through it transversely to its long diameter. These are the first perceptible changes in ova that are impregnated by the natural union of the sexes, and when spawning has not been retarded. But in some broods of eggs that have been retained longer than usual in the oviducts, the whole of these changes have

already taken place, in so far as regards those of the yelk, the white surface of which then exhibits an uniform appearance.

Changes immediately before segmentation or cleavage of the yelk.—Segmentation usually commences in from four to five hours. At about *one hour and a half* after spawning, the peripheral layer of cells on the middle of the dark or uppermost portion of the yelk of the impregnated ovum becomes separated from the inner surface of the vitelline membrane, and this separation goes on until a broad free space is left between this envelope and the superior layer of yelk-cells. This space, which we may designate the *respiratory chamber*, is at first but a small area above the middle of the dark surface of the yelk, and is commenced above the central canal. It seems to be occasioned by a recedence towards the interior, or a shrinking, at this period, of the yelk-cells of the dark hemisphere of the egg, commencing in the centre of this part and extending gradually, but in a less degree, to the circumference. This recedence goes on until the space left between the vitelline membrane and the yelk is equal to about one-sixth of the diameter of the whole mass, when the space appears to be occupied by a very transparent fluid, interposed between the now depressed surface of the yelk and the vitelline membrane. In the centre of the black surface is the minute orifice noticed by Prevost and Dumas*, and Baër†, which leads into the central canal that communicated with the germinal vesicle in the ovarian ovum. It is in the margins of this canal that segmentation is commenced. While the space or chamber between the black portion of the yelk and the vitelline membrane is being formed, and from fifteen to thirty minutes before there is any sign of cleavage, the yelk becomes extended horizontally in a direction transverse to that in which the first cleft afterwards takes place, and assumes a transitory obtuse oval form, which it retains until the yelk begins to divide. The division, as correctly shown by Baër‡, commences in the extension in opposite directions of at first a faint indentation in the margin of the central canal, which quickly becomes deeper, and is carried across the surface of the yelk, and gradually more and more deepening and widening as it proceeds, is carried round the sides, and meeting in the middle of the depression on the under surface, or of the remains of the white patch when this has not already disappeared, is completed by passing through the middle of the yelk; which is thus divided into two portions. This first division occupies from twenty to thirty minutes before it is finished, and it is not until then that a second fissure is commenced. I have not had any opportunity of proving whether this division is the direct result of subdivision of the central vesicle, and the attraction of the yelk-cells in equal proportions around each division of that body, as believed by Kölliker§, and, as it seems fair to infer, is the case; but in addition to the observation by Prof. Sharpey‖, that the contraction of the entire yelk at the commencement of these changes, and the movements he has observed among its granules as they proceed, are in favour of this opinion—I may remark, that the extension of the yelk of the Frog's

* *Loc. cit.* tom. ii. p. 104, 1824.
† Müller's Archiv, 1834.
‡ *Loc. cit.*
§ Müller's Archiv, 1843.
‖ Quain's Anat., Fifth Edition, 1848.

egg in a direction transverse to the first cleavage, may also be advanced as conformable to the same view. It is further supported by the fact which I have seen in the egg both of the Frog and Newts, that before the second or crucial cleavage is commenced the yelk becomes contracted, so that the first cleft for a time is almost imperceptible while it is extended in the transverse direction, or line of axis of the first division, after which the second or crucial cleft is commenced. To this I may add another fact which appears to be equally significant, and which occurs in the unimpregnated eggs both of the Frog and Newts, but more especially in the latter. Although no recedence of the yelk from the vitelline membrane takes place in the unimpregnated egg of the Frog, it becomes, nevertheless, slightly oval after the first few hours, but returns to its original shape some time afterwards. But the unimpregnated egg* of the Newts is not only separated from the vitelline membrane, but also is depressed, and has a distinct pit in the centre of its upper surface, and also assumes an obtuse oval form, both which it retains, when the egg is preserved in water, until decomposition has commenced.

Changes in the impregnated and unimpregnated Ovum compared.—Having traced the egg impregnated by natural union of the sexes through its first period of development, I was able to compare the phases it exhibits with those of the artificially impregnated, and these with the appearances in unimpregnated eggs of the same brood, placed under precisely similar circumstances with reference to light, heat, air, water, and locality. The ova experimented on were all procured from the same female, and the seminal fluid from the male with which she was paired, and at the time the female was about to spawn.

Spallanzani obtained unimpregnated eggs of the Frog for his experiments by opening the body of the female and removing them from the distended oviducts. This mode is exposed to the objection, that in the removal of the ova they are liable to be brought into contact with the blood of the animal from the cut vessels, and that the ova thus obtained may not be the most mature, and fitted for experiment. It seemed desirable, therefore, to obtain them by another mode,—the total withdrawal of the influence of sensation, and power of tension in the muscles by division of the spinal cord through the medulla oblongata. The attempt was made with a female frog that had been paired for several days, and, from appearances, would have deposited her ova naturally in the course of a few hours. The spinal cord was divided as quickly as possible with a strong pair of scissors immediately behind the brain, and this organ was also destroyed, so that all consciousness was annihilated. The attempt was successful. The muscles deprived of voluntary power instantly became relaxed and allowed of the ova being passed, by gentle compression of the body, through the natural passage without contact with the blood of the animal, in greater or smaller number at pleasure, and thus afforded easy means of experiment.

I may once for all state that it was in this way that the ova were always obtained in the following investigations.

* Or, possibly, partially impregnated.

Recourse was had to a similar expedient to procure the seminal fluid from the male. Spallanzani had obtained the fluid, by vivisection, from the seminal vesicles themselves. But there seemed more objection to the adoption of this mode with the male than the female, the certainty of much of the fluid being lost, independent of the severity of the operation. Indeed Spallanzani states, that he was never able to procure more than from two to three grains from a single individual. I therefore availed myself of a habit in the male frog, and which Spallanzani had previously noticed and taken similar advantage of in the Newt, to obtain the fluid in greater quantities than by the mode constantly adopted by that physiologist. When the male frog, like the Newt, is taken in the hand, or slightly compressed, at the season of pairing, a quantity of fluid is immediately passed. This consists chiefly of seminal fluid mixed with water expelled from the effect of the compression, or during the efforts to escape, as water is passed by other animals at the moment of capture. It abounds with spermatozoa in their most active state, and thus is fitted for experiment. It required therefore only to secure the limbs of the animal and compress it slightly, to obtain the fluid without severe injury. This ready mode was adopted on all occasions when the fluid was required, and the precaution taken always to examine a portion with the microscope, to be assured of its nature before employing it. Spermatozoa have never, during the season of pairing, been absent from it. At the end of the season they have been less abundant, and spermatozoal cells in greater proportion than at an earlier period. But in these cases I had reason to think that the chief part of the fluid consisted of water. It is probable that this was the case in the two instances of apparent absence of spermatozoa in the Toad, mentioned by Spallanzani*, and that the fluid did really contain spermatozoa, although few in number, and consequently easily overlooked, and that the ova were impregnated by these, and not by the fluid portion of the semen, as he appears to have supposed.

On comparing the white surface of the yelk of the unimpregnated with that of the impregnated egg, whether the egg had been fecundated naturally or artificially, I was not able to detect any difference during the first twelve minutes. The changes went on in both, and appeared to be almost identical in each. But after the time specified no further progress was perceptible in the unimpregnated ovum, which continued to exhibit the same appearance for several hours. But the white surface of the impregnated egg became more and more changed, up to the time of cleavage of the yelk, when it was almost an uniform surface.

These observations were afterwards repeated with similar results, and the conclusion to which they led was, that changes take place in the yelk from the period when the germinal vesicle disappears and the ovum leaves the ovary to the moment of its expulsion from the body, and which changes may proceed for some time afterwards quite independent of impregnation; and that these have some reference to the evolution of the central or embryo vesicle: possibly also that they do not cease imme-

* Dissertations relative to the Natural History of Animals and Vegetables, 1789, vol. ii. p. 151.

diately, but subside gradually when the stimulus imparted by impregnation is not supplied.

The experiments made to ascertain whether the unimpregnated ovum passes through any stage of cleavage, consisted of four sets, placed in four vessels of equal size, containing each about two ounces of water. Ova were passed from the same female as quickly as possible at the same time into each of these vessels. To one of these marked A, a considerable quantity of a mixture of seminal fluid, one part to three parts of water, was immediately added; to a second, B, only a single drop of this mixture; while the third and fourth, C and D, contained only water with the unimpregnated ova, and the four vessels were then placed in every other respect under precisely similar conditions.

A few minutes after the impregnating fluid had been added to A, I examined some of the ova beneath the microscope, and found a vast abundance of spermatozoa adhering to every part of the surface of their gelatinous envelopes. On other ova from the set B, there were also many spermatozoa attached, but in much smaller number than on the ova of set A.

In *five hours and fifteen minutes*, the temperature of the room during the interval having ranged only from 53° FAHR. to 54° FAHR., segmentation had commenced vigorously, and was strongly marked in the whole of set A. But it had not commenced in set B. It did not occur in these until *five hours and twenty-two minutes*, when it began in these also. Thus there were *seven minutes'* difference in the commencement of the changes in these two sets of ova, a circumstance which led to the belief that this difference might have some reference to the relative quantities of the impregnating fluid employed,—an opinion which I had long before been led to by observations on the impregnation of the common Earwig, *Forficula*, in which it had appeared to me that deficiency in the quantity of the impregnating fluid is unfavourable to fecundation.

No segmentation or cleavage of the yelk took place in the sets of ova marked C and D, which, except in becoming a little oval, as already mentioned of unimpregnated eggs, remained, in so far as the appearance of the yelk surface was concerned, in the same state as at a few minutes after spawning, and they continued in exactly the same condition at the end of twenty-two hours. This I have since found constantly to be the case with unimpregnated ova, whether they happen to be exposed to a high or low temperature of the surrounding medium. The yelk of the impregnated egg gradually acquires a more intense black colour, which strikingly contrasts with the dull colour of the unimpregnated.

At the end of *six days* the majority of the ova in A and B were producing embryos, while those in C and D were fast decomposing.

These trials afforded the positive test I required from direct observation, as a fixed point in the experiments about to be commenced,—that segmentation certainly does not take place in the unimpregnated ovum.

3. SUSCEPTIBILITY OF THE OVUM.

I was not aware, at the time of commencing my experiments in March 1849, nor indeed until very recently, of the extent to which the original investigations of Spallanzani, and of Prevost and Dumas had long ago been carried*, and it has only been since my experiments were completed, and during the preparation of this paper for presentation to the Royal Society, I have learned by careful reference to their first memoirs, that they have anticipated me in part of this inquiry—that of endeavouring to separate the spermatozoa by filtration from the more fluid portion of semen, and testing the effect of these two constituents in artificial impregnation. To them therefore be all honour for the result; although even they, as they honourably mention, had themselves been anticipated in this by Spallanzani, and that too with similar success. The extraordinary results obtained by Spallanzani† in artificial impregnation, and the imperfect knowledge which we possess of the nature of the means by which it is effected, has induced me to endeavour to repeat and vary his experiment, and to conceive others, which, so far as I am aware, have not yet been attempted. I have been the more urged to this from the circumstance mentioned by Spallanzani, and already alluded to (p. 189), the occasional supposed absence of spermatozoa from fluid that is capable of fecundating; and also from a belief formed long ago with regard to the Articulata, that the spermatozoa, nevertheless, certainly are the efficient agents in impregnation, although full proof of the fact has been wanted. I have been desirous therefore of learning how far this belief can bear the test of direct experiment, or the fact be capable of demonstration by artificial means in the Amphibia. As, however, the experiments I have myself made vary from those of the authors mentioned,—have not been influenced by the result they had previously arrived at,—have been somewhat more extended, and, as I believe, will now tend to place the fact of the direct agency of the spermatozoa in impregnating the ovum beyond doubt,—it has seemed desirable still to give them in detail, as assisting to establish an important point of knowledge by facilitating a comparison of the results of independent investigations.

Duration of susceptibility.—The length of time during which the ovum, after it has been passed, remains susceptible of fecundation, is affected by several circumstances. I had reason to believe at the commencement of my experiment that this time is very short. Spallanzani found that when the egg of the Toad was expelled into water it was not susceptible of fecundation after a lapse of fifteen minutes‡. This was at a raised temperature of the atmosphere, 81°·5 Fahr. On the other hand, he also found that, at this temperature, ova retained fourteen hours within the body of the female after death, and of course not in contact with air or water, might still be fecundated; and that when preserved in an ice-house fecundation might be effected at two days after the death of the parent§. But Prevost and Dumas arrived at the conclusion‖

* Annales des Sciences Naturelles, tom. i. et ii. 1824.

† Dissertations, &c. vol. ii.

‡ *Loc. cit.* vol. ii. p. 178.

§ *Loc. cit.* vol. ii. pp. 176 and 177.

‖ An. des Sc. Nat. vol. ii. p. 135.

that the time is much more extended in the Frog;—that fecundation may take place when the temperature ranges from 53° Fahr. to 59° Fahr. at the expiration of one hour after immersion of the eggs;—that some eggs are fecundated at two, and a very few even at the end of three hours, after which no fecundation takes place. The results obtained by myself both on the Frog and Toad have been most in accordance with those by Spallanzani. This is the more worthy of notice from the circumstance that a slight difference between his and mine is readily accounted for by a corresponding slight difference of temperature, which Spallanzani, and Prevost and Dumas, have remarked, and since them also Mr. Bell*, has great influence on the changes of the eggs and young. The temperature at which my test experiments were made, was a little lower even than that at which Prevost and Dumas made theirs; and yet I was not able to find any ova susceptible of fecundation after they had remained from thirty to forty minutes in water. On careful examination of Prevost and Dumas' experiments, I think the difference may perhaps be due to a circumstance which seems equally to affect some of Spallanzani's results, namely, the mode in which the impregnating fluid employed was obtained. These authors state that the fluid they employed was expressed from the testicles of the frogs, so that from what we now know of the mode of origin of the spermatozoa, this fluid in all probability contained a large proportion of developmental cells that included spermatozoa not fully matured, but which might become liberated in the water at a longer or shorter period. Or, possibly, the fluid added to ova that had been long in the water, had been very recently obtained; in which case the vigorous spermatozoa might effect the impregnation of ova that had become almost insusceptible through the imbibition of water by their envelopes. I am led to this view by the fact that the jelly-like envelope of the Frog's egg begins to imbibe and expand the instant it is brought into contact with fluid; and from having ascertained that there is a close relation between the degree of expansion and imbibition of this envelope and the susceptibility of the ovum to become impregnated, and that these conditions are also greatly affected by temperature. The act of expansion of the envelope is an act of endosmose, and possibly this is one of the means by which the impregnating agent is made to exert its influence on the yelk. The yelk is not a passive recipient during the endosmic action of its coverings, but seems to participate in that action, as I have seen portions of its surface heave and contract within the vitelline membrane during the first hour the egg has remained in water. It may thence be inferred, that if the impregnating stimulus be not supplied quickly, the fitness of the ovum to become impregnated is diminished in proportion as its envelopes are expanded. If then it be proved that the spermatozoon is the agent in impregnation, but, so far as can be discovered, does not penetrate bodily into the ovum or its envelopes, and yet, as may be shown, must always come into contact with their surface, the more rapidly and to the greater extent this expansion takes place, and removes the efficient body from that which it is in some way destined to affect, the

* British Reptiles, p. 92.

less will be the chance of its impregnating the ovum, and the less will the ovum become susceptible of impregnation even by the most healthy and vibratile spermatozoa.

The extent and rate of expansion of the envelope of the Frog's egg, during the first half-hour it remains in water, very nearly coincide with the diminution of the fitness of the ovum to become fecundated. This is shown by observing the rate of expansion of the envelope during the first fifteen minutes of submersion, and then testing the fitness of the ovum, by experiment, during a similar period.

At the *moment* when the ovum is expelled from the body, the envelope is merely a thin gelatinous layer, its entire diameter being equal only to about one-sixth of the diameter of the yelk. After it has been *one minute* in water, and begun to imbibe and expand, it is then equal to about one-fourth of the diameter of the yelk. At the end of *two minutes* it is enlarged to one-third, and in *three minutes* to one-half the diameter of this body. In *four minutes* it exceeds three-fifths, and in *six minutes* two-thirds, and it continues to imbibe fluid and expand at the same rate, until, at from *ten* to *fifteen* minutes, it very nearly equals in thickness the whole diameter of the yelk; and at *half an hour* (fig. 9) it is one-fourth greater than this. Prevost and Dumas* noticed the expansion of the envelope during the first *six hours*, but entirely overlooked the rate of expansion during the most important period, the first hour, and noticed only the general fact that the diameter of the envelope, at the end of the first hour and a half, was as 5 to 2·5 at the time of spawning, and that it had nearly acquired its full size at the end of three hours. My own observations agree with this latter statement. The expansion of the envelope is greatly retarded at the end of the third or fourth hour, until after cleavage of the yelk has taken place, when it again proceeds, but much more slowly than at first. If then we bear in mind the rate of expansion of the envelope during the first half-hour, the following experiments will give some idea of the degree of susceptibility of the ovum to become impregnated during that period.

Set E. April 6, 1850.—The temperature of the room, at the commencement of this set of experiments, being 60° Fahr., ova were obtained from a female frog and seminal fluid from a male, by the mode already mentioned; the latter being mixed with an equal quantity of water.

I may here remark, that the ova in each of this set of experiments were placed in nearly similar quantities of water, and that as it had been shown in the experiments A, B, C and D (p. 190), that segmentation of the yelk proves the ovum to have been impregnated, although, as we shall hereafter find, not always sufficiently so as to produce the embryo, I adopted this as a fair test of the susceptibility of the ovum. I may here also mention, that although the date of making the several experiments detailed in this paper is recorded, it has been necessary, for reasons that will be obvious, to disregard the order of time at which the several sets were

* *Loc. cit.*, vol. ii. p. 108.

made, and to detail them when considering the subject to which they more especially refer.

No. 1. P.M. $2^h\,52^m$.—*Eighty-three ova* were passed into water, and the impregnating fluid added to them at the expiration of *one minute*. This was *forty-three minutes* after the fluid had been obtained and mixed with water; but on examination with the microscope at this period, the spermatozoa contained in it were still very active. This long period was determined on with a view to the more effectually testing the susceptibility of the ovum, as it will be shown that the spermatozoa are less and less efficient in proportion to the length of time they have been mixed with water. Segmentation commenced in a very large proportion of the ova at the end of *three hours and fifty-five* minutes. On the 14th of April, the *eighth day*, *thirty-two* embryos had been formed.

No. 2. P.M. $2^h\,51^m$.—*Ninety-two ova* were passed into water, and at the expiration of *two minutes* impregnating fluid was added to the same, *forty-three minutes* after it had been obtained. Segmentation commenced in these also at *three hours and fifty-five minutes*, and took place in almost every ovum. On the *eighth day* there were *forty-five* embryos.

No. 3. P.M. $2^h\,24^m$.—*One hundred and twenty-seven ova* were immersed in water for *three minutes*, and then exposed and bathed with impregnating fluid during *twenty seconds*, water being immediately afterwards added to them. No segmentation had taken place at the end of *four hours and three minutes*, but it took place in many of the ova at a later period, the exact time having escaped my notice. The fluid employed had been mixed with water only *seventeen minutes*. On the *eighth day* there were *thirty-three* embryos.

No. 4. P.M. $2^h\,15^m$.—*Eighty-one ova* were exposed to the air on a dry surface for *three minutes* without having been in contact with water, and were then bathed with impregnating fluid during *five seconds* and water immediately afterwards added to them. The fluid in this experiment had been obtained only *eight minutes*. Segmentation commenced in several ova at *four hours and five minutes*, and on the eighth day there were *fifty-three* embryos.

No. 5. P.M. $2^h\,25^m$.—*One hundred and thirty-six ova* were passed into water for *five minutes*, and were then exposed and bathed with impregnating fluid for *several seconds*, and water immediately afterwards added to them. The fluid had been obtained *twenty minutes*. Segmentation occurred in one ovum at *four hours and eight minutes*, and in others quickly after. On the eighth day only *ten embryos* had been formed.

No. 6. P.M. $2^h\,17^m$.—*One hundred and thirty-nine ova* were exposed to the air, on a dry surface, for *five minutes*, and were then touched freely with fluid during *five seconds*, applied with a hair-pencil, and water was then quickly added to them. The fluid employed had been obtained *twelve minutes*. Segmentation took place in *four hours and eleven minutes*. On the eighth day there were *thirty-seven* embryos.

No. 7. P.M. $2^h\,21^m$.—*Two hundred and five ova* were retained in water for *fifteen*

minutes, were then exposed, well-bathed with impregnating fluid, and water immediately added to them. The fluid employed had been obtained *twenty-six minutes*. Segmentation commenced in *four hours and fourteen minutes*, but was more general in *four hours and seventeen minutes*. On the eighth day there were *forty-five* embryos.

No. 8. P.M. $2^h\ 24^m$.—*About one hundred ova* were submerged for *half an hour*, and impregnating fluid obtained *forty four minutes* before was then supplied to them, but not more than *six or eight ova* became segmented, and only two embryos were formed.

The following summary will more immediately indicate the results:—

TABLE I.—Set E.

Experiment.	Ova.	Time.	Medium.	Fluid obtained.	Segmentation.	Embryos.	Per-centage.
No. 1	83	1″	Water.	43″	3′ 55″	32	·38
No. 2	92	2	Water.	43	3 55	45	·49
No. 3	127	3	Water.	17	4 3	33	·26
No. 4	81	3	Air.	8	4 5	53	·65·5
No. 5	136	5	Water.	20	4 8	10	·07
No. 6	139	5	Air.	12	4 11	37	·26
No. 7	205	15	Water.	26	4 14	45	·22
No. 8	100	30	Water.	44	.....	2	·02

Thus then at a temperature of 60° FAHR. the susceptibility of the ovum to become impregnated is greatest at the time it is passed into water, and for two or three minutes afterwards, and segmentation then takes place more quickly, even when the seminal fluid has been for nearly three quarters of an hour mixed with water, than after longer immersion. The fitness of the ovum to become impregnated is gradually diminished, and segmentation takes place more tardily, according to the length of time which the ovum has remained in water, as is seen by comparing the results of Nos. 1 and 2 with 7 and 8. On the other hand, while the desiccating effect of exposure to air more arrests the fecundation of the ovum and the occurrence of segmentation of the yelk than a continuance for a corresponding length of time in water, it seems to be less prejudicial to the fecundity of the ovum than immersion in that fluid, as appears to be shown by comparison of Nos. 4 and 6 with 3 and 5, the difference in the number of ova produced being too great to lead us to attribute this to difference in the length of time the impregnating fluid had been obtained.

In the foregoing set of experiments, the quantity of impregnating fluid supplied to the ova was but little attended to, it being added very freely in each case. In the following set I was desirous of knowing what difference would result from the fluid being applied more sparingly, or but for a very short space of time. SPALLANZANI had made experiments with a similar view, but his appeared to be open to some objections, as he had not noted some important circumstances which greatly affect the result, as the temperature of the medium, the length of time the fluid employed had been obtained, &c. In the experiments now made, these circumstances were

attended to, and I noticed a curious fact which I first remarked in experiments in 1849. It is what I may designate *partial impregnation*, and is indicated by a portion only of the yelk becoming segmented. This frequently happens with ova that have been brought into contact with only very small quantities of seminal fluid, and but for short spaces of time, as in some of the following experiments. These ova, so far as I have observed, never produce embryos. Segmentation is arrested in some at the very commencement (Plate XIV. fig. 11), in others it goes on to the second or crucial fissure, and in a very few cases may proceed somewhat further (fig. 12), but is never completed to granulation of the yelk. This, I think, is a fact which deserves some consideration with reference to the formation of the embryo.

Set F. March 22, 1850.—Temperature of the room at the time of the experiment was 48°·5 Fahr., and that of the water employed 46°·5 Fahr. As the proof of impregnation is the segmentation of the yelk, and as my object now was to observe the effect of small quantities of impregnating fluid applied only for very short periods of time at a low temperature of the surrounding medium, it is not of consequence that this set was not watched to the full development of the embryo. To show the degree of susceptibility of the ovum under the combined influence of these circumstances, it was sufficient to attempt the impregnation at a low temperature, and after the lapse of an interval to remove the ova to a room of the same, or nearly the same temperature as in the set E. This was done at the end of one *hour and a half*.

No. 1. A.M. $12^h\ 12^m$.—*Fifty-one ova*, passed on a dry surface, were each touched lightly and quickly, *once* only, with a small hair-pencil dipped in impregnating fluid mixed with water, at *eleven minutes* after it was obtained, and water was then added to them. At the expiration of one hour and a half they were removed to a room of the temperature of 59° Fahr. Segmentation did not occur until the expiration of *six hours* and *a half*, and at the end of eight days only *four* embryos had appeared.

No. 2. A.M. $12^h\ 20^m$.—*Forty-two ova* were immersed in water for *five minutes*, and then exposed, and touched for an instant only as above, and again placed in water. The impregnating fluid had now been obtained *nineteen minutes*. Segmentation commenced in some of these at *six hours and three quarters*, but nearly all of them were only *partially impregnated*, and not a single specimen produced an embryo.

No. 3. A.M. $12^h\ 19^m$.—*Fifty-eight ova* immersed in water for *five* minutes, were exposed, touched for an instant as above, and again immersed for *one minute*, after which, they were well rubbed in the water with a clean pencil, and fresh water then supplied to them. The fluid employed had been obtained *twenty-three* minutes.

Not a single egg gave any signs of having been impregnated, either perfectly or partially, nor did a single ovum produce an embryo.

No. 4. A.M. $12^h\ 23^m$.—*Forty-two ova* were passed into a solution of *carmine* (the pigment employed by water-colour painters) for *five minutes*, and were then washed with water, touched for an instant, as above, with impregnating fluid at *twenty-seven minutes* after it was obtained, and water then supplied to them. Not a single egg

became fully impregnated or afterwards produced an embryo. In two or three ova there were slight indications of partial impregnation.

No. 5. P.M. $12^h\ 37^m$.—*Sixty-five ova* having remained *fifteen minutes in water*, were exposed, and thoroughly bathed with impregnating fluid applied with a hair-pencil, *fifty-one* minutes after it had been obtained, and water was then added to them. Segmentation did not take place in these ova.

No. 6. P.M. $12^h\ 38^m$.—*Seventy-seven ova*, passed into a *solution of carmine* for *fifteen minutes*, were exposed, and thoroughly bathed with impregnating fluid as in No. 5, and water was then added; but not a single egg gave any sign of impregnation.

Influence of Temperature.—From these experiments, it seemed evident that the susceptibility of the ovum to become impregnated is diminished in proportion to the degree of expansion of its envelope and its imbibition of fluid, conditions which are greatly affected by the temperature of the medium in which the ovum is placed during the first hour; and there seems reason to suppose that this diminution may be due to the extent to which the envelope becomes influenced by temperature, rather than to any insusceptibility at that time in the yelk itself. The following experiments, made a few hours after the above, tend to support this view.

Set G. March 22, 1850. Atmosphere 48° FAHR. Water 47°.

No. 1. P.M. $4^h\ 30^m$.—*Fifty-eight ova* were passed from the female from which the ova used in the preceding experiments were obtained, four hours and a half after division of the spinal cord; and seminal fluid mixed with water, and obtained *fifteen minutes* before, was *immediately* added to the water in which they were immersed. The ova were removed at the end of twenty-five minutes to a room in which the temperature was then 62° FAHR. Segmentation took place in almost every ovum a few minutes *within* the *sixth hour*, at which time the temperature of the air was 64° FAHR., and that of the water 62°. At the *eighth* day, *fifty-three* out of fifty-eight ova had produced embryos.

No. 2. P.M. 5^h.—*Sixty-three ova* from the same female were well bathed with impregnating fluid, and water was then added to them. The fluid in this case had been obtained three quarters of an hour. Segmentation took place in the majority of these at the end of *five hours and a half*.

No. 3. March 23. P.M. $12^h\ 45^m$.—*One hundred and twenty-four ova* from the same female, twenty-four hours after section of the spinal cord, were passed into water, and impregnating fluid soon after it was obtained supplied to them. The ova were placed in a temperature of about 60°, and nearly the whole produced embryos.

These facts proved that the ova employed were still fitted to become impregnated when the fluid was supplied to them in sufficient abundance, and for a sufficient length of time, and within the period during which the envelope continues to expand and imbibe most rapidly. This condition is always promoted by an early removal from a low to a comparatively high temperature during the period of expansion, as in *Set* G, in which segmentation took place in from *five hours and a half to six hours*, and when

the removal from low to high temperature was within the first half hour; while it did not occur, in the only experiment in which it happened in *Set* F, No. 1, until the end of *six hours and a-half*, when the removal from a similar low to a like high temperature was not made until one hour and a half after impregnation.

The influence of temperature is thus as marked in its effects on the impregnation of the ovum as it can be proved to be on the future development of the embryo. Impregnation is accelerated, and also is more certain in its occurrence in a high than in a low temperature. In the latter it becomes retarded and is less determined. This applies equally to the susceptibility of the ovum, and to the fitness of the impregnating fluid to effect impregnation. But in proportion as this fitness is exalted by increase of temperature, so is the duration of the capability to receive in the one, and the efficiency to communicate in the other diminished. SPALLANZANI found that the ova of toads placed in an ice-house could be impregnated at the end of forty-one hours*. PREVOST and DUMAS† also mention that they were successful, and that too to a great extent, with ova that had been twenty-four hours *in water*, the temperature during the period ranging from 18° Cent. (64°·4 FAHR.) to 22° Cent. (71°·6 FAHR.), and with some eggs that had not been immersed even at thirty-six hours‡, the temperature being then from 12° Cent. to 15° Cent. (53°·6 to 59° FAHR.). The results obtained by myself have been much less successful. Out of one hundred and forty ova obtained from a female frog, killed twenty-four hours before and preserved at or below the temperature of 55°·5 FAHR., at which the experiment was made, only a very few became partially segmented, but not one produced an embryo; although an abundance of impregnating fluid, abounding with spermatozoa, and obtained only a few minutes before it was employed, had been supplied to them. It is evident therefore that this failure was due chiefly to the ova, and not to inefficiency of the impregnating fluid. On the other hand, I have been equally unsuccessful with ova from a frog that had been killed only two hours and a half when the impregnating fluid employed had been more than four hours and a half mixed with water. In this case the failure appeared to have been due chiefly to the spermatozoa, nearly the whole of which, on inspection by the microscope, were found to be motionless and appeared to have lost their vitality. At the same time it must be mentioned that the female from which the ova employed in No. 3 of the last set of experiments were obtained still existed, in so far as the vitality of the muscular system was concerned, and therefore can hardly be mentioned in comparison with MM. PREVOST and DUMAS' observation. But while the numerical results obtained by myself have been less favourable than those of SPALLANZANI or the physiologists now mentioned, the general facts, so far as they are open to comparison, are in full accordance with them. The difference in the details of our respective observations appears to have been due in chief part to the influence of temperature at the time of the impregnation of the ova, or within the first two or three hours after the impregnating fluid has been supplied. Thus, if the temperature

* Dissertations, &c., vol. ii. p. 177. † *Loc. cit.*, vol. ii. p. 140. ‡ *Id.*, p. 134.

has been gradually rising at the time of impregnation, the fecundation of the ovum, as I have stated, has more certainly taken place than when the temperature was subsiding, the condition of the ova and of the impregnating fluid employed being equally fit in each case. Spallanzani has shown that in his experiments ova did not become impregnated after they had remained fifteen minutes in water. In the experiments by myself I could rarely obtain fecundation after thirty minutes' immersion. The difference of time between these results may fairly be attributed to difference in the temperature at which the experiments were made, and in great measure to the influence of this on the endosmosis and expansion of the envelopes. But it was possible that some other agent might be concerned in these results, and that light, as well as heat and immersion in water, might greatly influence them. To put this to the test, and to learn whether the difference depends entirely or chiefly on the amount of temperature, I have made two sets of experiments at precisely the same time, performed in the same way, with ova from the same female and impregnating fluid from the same male, the only difference being that within a very few minutes after the impregnating fluid was supplied, one set was removed to a higher and slightly rising temperature, from which all light was excluded; while the other was allowed to remain freely exposed to light, but in a room of ten or twelve degrees lower temperature, and which was becoming still further reduced.

The influence of light and heat on the development of the embryo has already been referred to by Spallanzani, Prevost and Dumas, Rusconi, Dr. W. Edwards, and Mr. Bell. Rusconi expressly states that light has no influence on the development of the germ*, but his observations, as well as those before made by Spallanzani, show that heat has a very marked influence, and this has been fully confirmed by Dr. W. Edwards, and Professor Bell. Very recently also the subject has been referred to by Mr. Higginbottom†, and I have great pleasure in stating that my own observations on the influence of heat, and the little effect of light on the development of the tadpole, are in accordance with the observations made by him. But the object I have had most in view has been, as above stated, to mark the effect of heat, without light, on the changes of the ovum, more especially during the period of fecundation, the first three or four hours after the egg is laid; and onwards to the termination of what I shall hereafter propose to consider, when describing the development of the embryo,—as the end of the *third period*—the closure of the *laminæ dorsales* and the establishment of ciliary aëration on the surface of the body.

Set H, March 20, 1850. Atmosphere 59° Fahr. Water 57° Fahr.

No. 1. P.M. 1^h 14^m.—*Eighteen ova*, as they passed from the body of a frog, were touched lightly *once* with a hair-pencil that had been dipped in impregnating fluid obtained two minutes before, and mixed with about three parts of water. After these ova had remained ten minutes in water, this was removed and fresh supplied.

These ova assumed the ovoid form at the expiration of three hours and thirty-six

* *Loc. cit.*, p. 20. † Proceedings of the Royal Society, May 16, 1850; and Phil. Trans. Part II., 1850.

minutes, and segmentation commenced at *three hours and fifty-six minutes*, and was general in two minutes longer, at which time the temperature of the dark cupboard in which the ova of this set of experiments were placed had been raised to 64° Fahr., and that of the water they were contained in to 60° Fahr.

In four days and a half, *thirteen* of these ova had produced embryos that were then at the end of the *third period* of development, and on the eighth day the whole of them had advanced to the period when they leave the ovum and attach themselves to the exterior of the envelopes,—the end of the *fourth period* of development. The mean temperature of the locality in which these ova and the embryos produced from them were placed, was about 60° Fahr. for the entire period of eight days.

No. 2. P.M. 1^h 55^m.—*Forty-eight ova* were touched *once*, as they passed from the body of the frog, with a hair-pencil that had been dipped in a small quantity of residual fluid retained with spermatozoa on a filter, in separating these from the fluid portion of frog's semen, obtained and mixed with water forty minutes previous.

The temperature of the cupboard having been raised as in No. 1, segmentation commenced in *three hours* and *fifty-five minutes*, but was more general in *four hours*. Many of these ova were only partially impregnated, and of consequence did not produce embryos. Others passed through their changes, as in No. 1, and in nearly similar periods of time. On the eighth day *ten embryos* had been produced.

No. 3. P.M. 2^h 3^m.—*Fifty-seven ova* were well bathed as they passed from the frog with the fluid portion of semen that had passed through two filter papers and been separated from most of the spermatozoa, and which when examined with the microscope was found to contain only a very few of these bodies.

No segmentation had taken place in any of these ova at the end of *four hours and five minutes*, but several had become ovoid. At *four hours and thirty-seven minutes* segmentation had taken place in *one ovum*, and this alone produced an embryo.

Set I, March 20, 1850. Atmosphere 48° Fahr. Water 47° Fahr.—This set was the counterpart of the preceding, *Set* H.

No. 1. P.M. 1^h 15^m.—*Nineteen ova* were treated in exactly the same way as in No. 1 H, and at the expiration of ten minutes were removed to fresh water, and placed where they were most exposed to light.

No segmentation occurred in any of these ova until the expiration of *seven hours and forty-five minutes*. The temperature of the room had then sunk to 47° Fahr., and that of the water with the ova to 46° Fahr. All the changes in these ova were so exceedingly slow, that at the end of the eighteenth hour, the temperature during the interval becoming slightly further reduced, the segmentation of the yelk had not advanced further than to the formation of the first equatorial and secondary median furrows. On the fifth day the development of the germ had not proceeded further than to the commencement of the formation of the *area germinativa*, the end of the *second period*, the mean temperature during the interval having been 45°·49 Fahr.; while the ova in No. 1 H had reached the end of the third period, the mean tem-

perature in which they had been retained being 59°·5 Fahr. On the *eighth day*, when, as already shown, the *thirteen embryos* of No. 1 H had left the egg, only *three* had been developed in this set of observations, No. 1 I, and these had reached only to the commencement of the formation of the laminæ dorsales, the mean temperature of the room during the entire period being then advanced to 45°·72 Fahr.; and the completion of their third phase of development did not take place until the *tenth or eleventh day*.

Thus while *three embryos* only were produced in this experiment, No. 1 I, during exposure to light and at a mean temperature now raised to 47°·38 Fahr., *thirteen* in No. 1 H were developed in about one-half the space of time from a similar number of eggs removed from the light, and at a mean temperature of 59°·5 Fahr.; so that we seem here to have good reason to believe that a low temperature of the medium not only retards the development of the embryo, even when exposed to light, but injuriously affects the fecundation of the ovum.

The result of the next experiment coincides with the above.

No. 2. P.M. $1^h\,56^m$.—*Fifty-one ova* were touched in the same way with spermatozoa from the filter paper, as in No. 2 H, and were retained in the same temperature as the preceding.

A few of the yelks became ovoid in about *six hours*, but segmentation did not commence until *seven hours and two minutes*, and then only in a very few. *Two embryos* only were produced from this set.

No. 3. P.M. $2^h\,5^m$.—*Fifty-five ova* were bathed with filtered fluid in exactly the same way as in No. 3 H; but not a single ovum became segmented. Not one produced an embryo.

Thus while segmentation took place in No. 1 H, in three hours and fifty-six minutes, when the temperature was rising from 59° Fahr. to 64° Fahr., it did not occur in No. 1 I, until seven hours and forty-five minutes, when the temperature during the interval was sinking from 48° Fahr. to 47° Fahr. This sufficiently marks the great influence of temperature during the earliest periods of change in the ovum; and this injurious effect of reduction of temperature at that period is further shown in the relative number of embryos in these comparative experiments. That the injurious effect of reduced temperature at the time of impregnation is mainly the cause of this result, and not the diminution of temperature after the period of impregnation, seems to be shown in the circumstance, that while at the end of the eighteenth hour the ova in the set H had already passed through all the stages of segmentation, and the surface of the yelk had become granulated, and the blastoderma had begun to be formed even although the temperature in that case subsided a little after segmentation had commenced,—from 59° to 57°,—the corresponding set of ova, No. 1 I, had advanced only to the octuple division of the yelk. A similar difference in the rate of development we have seen takes place in the growth of the embryo. At the end of three days the embryos of set H were advanced to the stage at which the laminæ

dorsales are proceeding rapidly to meet, and form the median dorsal sulcus of the growing body. But the corresponding ova in set I had not been carried further than to the earliest perceptible indications of the *area germinativa*.

These facts sufficiently prove the great influence of temperature on the development of the embryo in its earliest stages, as the comparative numerical results do also its effects on the impregnation of the ovum. Out of eighteen ova placed in the higher and increasing temperature, thirteen produced embryos at nearly similar stages of growth; while of nineteen ova maintained in a low and diminishing temperature only eight became segmented, and but three of them arrived at the tadpole state.

A somewhat similar but more marked result took place with the ova of No. 2 in the two sets of experiments. The impregnating means employed in these trials had already been forty minutes mixed with water on the filter. Out of forty-eight ova employed in set H, twenty-five became segmented, and ten of these produced young. But in set I fifty-one ova gave birth to only two embryos.

In the third experiment of each set the difference is as strongly marked. As the filtered fluid employed in both was the same, and the very few spermatozoa contained in it were by the same means brought into contact with the ova in each, it might have been expected that each would have produced embryos. But while the production of a single tadpole in the one case, at a high temperature, may be looked upon as leading to the inference that these bodies are the efficient agents in impregnation, the entire absence of all appearance of impregnation in the ova of the other set, to which the same fluid had been equally applied, seems to point to the cause of failure in this case as depending on the prejudicial effect of a low temperature of the surrounding medium on their agency.

The temperature of the surrounding medium ought, therefore, always to be borne in mind when we are attempting to deduce conclusions from experiment on impregnation and development. The presence of light appears to be only of secondary consideration as compared with heat; since in set H, from which light was carefully excluded, not only did impregnation take place more certainly and rapidly than in set I which were exposed to light, but the embryos also were produced in greater number, and acquired maturity in less than one-half the space of time than in the latter; the only difference of circumstance between the two sets being degree of temperature.

Influence of Aëration.—Next in importance to heat is a free *aëration* of the ovum. This is of less consequence with reference to impregnation than to the subsequent production of the embryo. In every set of experiments there are always some ova more advanced than others. These are ova which have been nearest to the surface of the water, and which, consequently, have been more completely aërated as well as exposed to a slightly higher temperature than others at a greater depth. It is from this cause chiefly that the results of experiments on artificial impregnation, and even of observations on naturally impregnated ova, are always less complete and

successful than what takes place with regard to the ova in the natural haunts of the species. The ova in a state of nature are usually deposited in well-aërated places, clear, slow-moving water, or shallow and but slightly turbid water. It is almost impossible to afford to ova that are the subjects of experiment, either in broad flat dishes, or in glass vessels in one's study, the amount of aëration required to ensure complete success. By too frequently changing the water in the vessels the embryos often become injured; while if the water be not changed, development is arrested, and decomposition commences, and the experiment entirely fails. Even when these difficulties are obviated by a gentle withdrawal of the water, and a renewal of it with equal care, the perfect stillness of the fluid in the interval of our observations does not allow of that extent of aëration to the embryo which it gains in a perfectly natural state, either in slow-moving waters, where I have usually found the eggs deposited, or in pools of still water, the surface of which is agitated by currents of air, and affected by diurnal changes of temperature.

Thus then we may conclude that the procreative force of the germ, and of the impregnating fluid, is augmented by increase of heat, but the duration of the force is lessened. It becomes less and less energetic in proportion as the temperature is diminished, but the period during which it is capable of being exerted is extended. In each of these conditions aëration is of essential consequence, and becomes more and more necessary in proportion to the increase of heat.

4. THE AGENCY OF THE SPERMATOZOA IN IMPREGNATION.

It is evident from the last-mentioned experiments, that however great may be the influence of temperature in accelerating or retarding impregnation and development, and however much the operation of this influence may be interfered with by want of proper aëration of the ovum, the impregnating force does not equally pertain to all parts of the seminal fluid, but is to be found in some only of its constituents. Experiments made before those now detailed,—and to which I had been led by a conviction that the opinion formerly entertained, that impregnation is effected through means of the fluid portion only of the semen, was not in accordance with facts I had very long been acquainted with in the Articulata,—convinced me that the spermatozoa themselves, and not the other constituents of the semen, are the efficient agents of impregnation. Leewenhoek, and, as I have since found, Prevost and Dumas, not only believed this to be the fact, but also held the opinion that the spermatozoa penetrate bodily into the ovum; and this view has been more recently insisted on by Dr. Martin Barry, with the additional belief that a perforation or fissure exists in the envelopes of the ovum, through which the spermatozoon enters. On careful examination of the envelopes of the ovum of the Frog, I have not been able to detect any fissure or orifice. The question of the agency of the spermatozoa, nevertheless, appears to be capable of solution, however difficult it may be to ascertain the mode and particular nature of such agency. The separation, as far as possible, of

the spermatozoa, by filtration from the fluid in which they move, and testing the ova with these and the fluid separately, afford good proof of the agency of these bodies; while immersion of the ova in coloured fluids, at the moment of their passage from the body of the frog, seems equally fitted to ascertain the believed existence of a fissure or perforation through the envelopes during their expansion. The experiment of filtration was originally performed by Prevost and Dumas with well-marked results, and it has since been repeated by the first of these observers * by a different mode, —endosmose through the operation of galvanic currents. The mode pursued by myself was that originally adopted by these observers:—careful mechanical filtration, by simply passing the fluid portion of diluted semen through folds of filtering-paper. The paper I have employed, and which alone was fitted for the purpose, was the best Swedish filtering-paper employed by chemists in their most delicate analyses. A large proportion of the spermatozoa were always retained, even on a single filter, although a few usually passed through; but this, as the results show, was not in reality a disadvantage, when a few only were present in the filtered portion. When three or four folds of filtering-paper were employed, the whole of the spermatozoa were removed.

Filtration of Seminal Fluid.—Fluid obtained from a male frog, immediately after removal from the female, was mixed with about twice its quantity of water and placed on the filter. Portions of this fluid as they passed through were repeatedly examined with the microscope. Some of these filtered specimens contained a very few spermatozoa, usually not more than three or four in the drop examined, but sufficient occasionally, as the results proved, to effect impregnation.

Filtration Experiments.—Set K. March 14, 1849. Atmosphere 55°·5 Fahr. Water 55° Fahr.

No. 1. A *single drop* of the *filtered fluid* was added to one ounce of water, in which *forty-six ova* were immersed. Not a single egg became segmented or produced an embryo.

No. 2. A *single drop* of the diluted fluid, *not filtered*, but two hours after it had been obtained, was added to one ounce of water with *ninety ova*. Not a single egg was segmented or produced an embryo.

No. 3. *Two drops* of *filtered fluid* were added to one ounce of water with *sixty ova*, but not one egg became impregnated.

No. 4. *Three drops* of *filtered fluid* were added to one ounce of water with *one hundred and five ova*. *Two* of these were partially impregnated, as shown by their becoming imperfectly segmented (Plate XIV. fig. 11 and 12), but neither of them produced an embryo.

No. 5. *Three drops* of diluted fluid, *not filtered*, but two hours after being mixed with water, were added to one ounce of water with *seventy-six ova*. Several of these became segmented, but more tardily than in the following experiment, No. 7. At the end of seventeen days *fifteen* embryos had been produced from these ova.

* Journal de l'Institut, 1840, No. 362, p. 908.

No. 6. *Thirty drops* of *filtered fluid* were added to one ounce of water with *two hundred and ten ova*. At the expiration of five hours two ova had become segmented, and two embryos were afterwards produced.

No. 7. *Thirty drops* of diluted fluid, *not filtered*, were added to water with *two hundred and fifty ova*. At *four hours and forty-two minutes* segmentation had commenced in two or three of these, and in *five hours* had occurred in almost every ovum. Nearly the whole of these produced embryos.

No. 8. About *thirty drops* of the same diluted fluid, *not filtered*, were added to water that contained about *two hundred ova*, passed from the body of a frog killed twenty hours before. A few of these ova became imperfectly segmented, but not one produced an embryo.

From these first experiments with filtered fluid, it seemed that the portion of semen which passes through the filter has not the power of impregnating, unless there are spermatozoa present in it; while similar quantities of diluted semen that has not been filtered, are efficient and impregnate, as in Nos. 4, 5, 6 and 7. Further, it is shown, from No. 8, if we may judge from one experiment, that ova which have remained in the body of a frog twenty hours after actual death and cessation of the organic functions, and in a temperature of 55° Fahr., may be affected by the stimulus of the impregnating fluid, but not sufficiently so perhaps as to result in fruitful impregnation.

During the time these ova were under observation, in March 1849, an opportunity occurred of observing the effect of reduced temperature on the rate of development of the embryo when its formation has been somewhat advanced. On the seventh, eighth and ninth days after impregnation of the ovum, and when the temperature had already been considerably reduced, the season became severe, and in order to test the effects of cold, the eggs were removed to the open air and exposed to a keen wind. The temperature of the atmosphere was then 38° Fahr. During the night of the tenth day, the water in which the ova were contained was frozen to a mass of ice. Yet many of these ova, as above shown, produced embryos. Spallanzani had already remarked, that the eggs of the Frog may be inclosed in ice, and yet afterwards produce embryos, if the envelope does not become frozen*.

The experiments made to ascertain whether cleavage of the yelk may be taken as a test of impregnation (p. 190), seemed also to show that, *within certain limits*, a large or small quantity of seminal fluid has some influence on the more or less early occurrence of this phenomenon. It occurred to me, therefore, that in making the experiments now given, two questions might be examined: one, as to whether the extremely minute quantities of seminal fluid disseminated in water, as mentioned by Spallanzani, are as efficient to produce the embryo at the low temperature of the season at which the Frog spawns in this country, as in the warmer region of Italy; and the other, whether the presumed efficiency of such minute quantities depended on the presence of the spermatozoa; and it seemed possible to put these

* Dissertations, &c., vol. ii. p. 49.

questions to the test in one set of experiments. But, in attempting to do so, it was a matter of importance, first, to obtain some approximative knowledge of the actual quantity of spermatic fluid employed by Spallanzani, in his more remarkable experiments, to enable me to compare the results of my observations with those of his. Spallanzani states, that by his mode of obtaining the seminal fluid, by vivisection, he could only procure from "two to three grains*" from each individual. Three *grains* weight of fluid are equal, by measure, to nearly three *minims* of our medicinal standard. But it may be presumed that in so delicate an operation as that of removing the fluid from the vesiculæ seminales, from which Spallanzani states he usually obtained it, he could rarely be very precise in his determination of the quantity. I assume, therefore, for the sake of comparison, that the quantity he speaks of as "a *grain*" was about equal to a *minim* of our medicinal measure. Three grains of fluid (? minims), he says, were mixed with a *pint and a half* of water, and one *drop* of this mixture (the seminal fluid in which was equal to $\frac{1}{3840}$th part of the whole at 16 oz. per pint) applied directly to an ovum on the point of a needle, was "frequently" sufficient to render it fruitful†. The *drop* spoken of in this experiment was a much less quantity than the grain or minim; indeed, Spallanzani states that it did not exceed the "fiftieth of a line" (? fifth) in diameter. The quantity of fluid obtained by myself from a frog was usually about *six minims*, and this I mixed with twice its quantity of water, thus making eighteen minims. One *drop* of this mixed fluid measured, as I found, one-third of a minim, and consequently contained one-third part of seminal fluid, or one-ninth of a minim of the seminal fluid. Yet the result of the employment of one drop of this mixed fluid added to one ounce of water, in which the proportion of seminal fluid was then made to be $\frac{1}{4320}$th part of the whole, did not lead to the same result as the experiment by Spallanzani. The difference arose, perhaps, from the operation of two or more causes:—first, the much lower temperature of the atmosphere at the time of making my experiment, than at that of Spallanzani's; next, the diminished efficiency of the seminal fluid, owing to the length of time (two hours) it had been removed from the body. Both these circumstances, but especially the first, as already shown, operate unfavourably in experiments on impregnation, more eggs being fertilized at a high temperature, when the changes go on rapidly, and especially when the seminal fluid has been most recently obtained, than under the opposite conditions. The general results of my experiments, however, may be regarded as quite confirmatory of Spallanzani's more remarkable one, as they prove, like that, that only an exceedingly small proportion of seminal fluid is necessary to fertilize the ovum.

* *Loc. cit.*, vol. ii. p. 189.

† *Loc. cit.*, vol. ii. p. 192. There is some confusion of statement in the translation of Spallanzani's work, now referred to, respecting the quantities mentioned by the author, as "pint" is the word used in some passages and "pound" in others (p. 191), apparently synonymously, while the latter is further spoken of as "twelve ounces."—G. N.

But however satisfactory these experiments were with regard to that fact, they still left the question of the immediate agency of the spermatozoa in impregnation in doubt. I therefore repeated them with greater precision, and with that object only in view, and took especial care to obtain as perfect a filtration and separation of the spermatozoa from the fluid as possible. The results were far more interesting and instructive than I had anticipated, as I found by repeated examination by the microscope that the filtered fluid was almost completely deprived of spermatozoa, one or two only being occasionally detected in it, with a very few nuclei and spermatozoal cells. One circumstance that tended to increase the value of this set of experiments, and to prove the influence of the spermatozoa, was, that the ova employed were not fully matured, and hence I had less expectation of a favourable result. The quantity of seminal fluid obtained was larger than usual, and this was mixed with twice its quantity of water. This mixed fluid was divided, as before, into two portions, one of which was filtered, and the other not. The experiments were commenced in the early part of the day, and the temperature of the atmosphere of the room, and that of the water employed, was nearly the same, 51° Fahr., and the whole of the experiments were placed as nearly as possible under similar circumstances.

Set L. March 18, 1849. Atmosphere 51° Fahr. Water 51° Fahr.

No. 1. *Ten minims* of the mixed fluid were added to two ounces of water, into which *one hundred and fifty ova* were immediately passed. One hour afterwards I found a great abundance of spermatozoa adhering to the surface of the envelopes. Segmentation of the yelk commenced in *five hours and forty minutes* in a few ova; and took place in others at a later period. A few only of these ova produced embryos.

No. 2. *Ten minims* of the filtered portion of the mixed fluid were added to two ounces of water, and about *one hundred and fifty ova* were passed into it. When these ova were examined at the expiration of an hour, not a single spermatozoon was detected on any of them; and when repeatedly examined at the end of five and six hours, not one showed any signs of cleavage. This change did not take place in any of them even at a later period, and *not one produced an embryo.*

As the ova in these two experiments were the first that passed from the body of the Frog, it was fair to regard them as being the most matured; segmentation ought, therefore, if it occurred at all, to have taken place at an earlier period in these than in others afterwards obtained from the same female.

No. 3. *The filter paper* employed in separating the fluid used in the last experiment, No. 2, and which retained the separated spermatozoa in a minute quantity of fluid that had not passed through, was placed in two ounces of water, and *one hundred and thirty ova* from the same female were shed upon it. When some of these ova were examined at the end of an hour and a half, spermatozoa in vast abundance were found adhering to every part of their surface, but the whole were then motionless, and apparently dead and partially coiled on themselves (Plate XIV. fig. 8 *c*). In

some of these the body appeared to be slightly enlarged. Segmentation commenced in very many of these ova in *five hours and ten minutes*, and was almost universal in them a few minutes later. *Nearly the whole of these ova produced embryos*, there being only nine out of the one hundred and thirty that were abortive. I have sometimes found a much larger proportional number of unproductive ova in some broods in the natural haunts of the Frog.

There was one exceedingly interesting fact in this experiment,—it was that the smaller and apparently less matured ova were as fully impregnated as the larger and more perfect. The whole set of observations was the more interesting from this circumstance. These ova were smaller than usual and had not the white surface so complete, but were very like the ova in which I have described the changes in the light-coloured surface (p. 185). When first placed in water with the filter paper and spermatozoa, the surface of the yelks became more contracted and irregular, within the vitelline membrane, than in other ova I have employed. Hence I had much doubt, at first, whether any satisfactory evidence would be obtained from this set. But the contrary has been the case, as it is evident that some ova may be impregnated at a little earlier period than usual; and that when a great abundance of spermatozoa is supplied, ova less matured than others may be equally well impregnated. The greater efficiency of a larger as compared with a small number of spermatozoa, with reference to the earlier or later segmentation of the yelk, has already been shown; and the difference is very marked in the first and third of this set of experiments, both with reference to the occurrence of segmentation and to the relative fecundity of the ova. On the other hand, the experiment No. 2 proved that the *liquor seminis is not* the fecundating portion of the seminal fluid.

Circumstances having prevented me from making known the result of these experiments at the time they were obtained, I determined, during the past spring, to repeat and vary them, to obtain, if possible, still more conclusive proofs that the spermatozoa alone effect impregnation. Accordingly, in March and April of the present year (1850) I repeated them, with the following precautions:—first, that the frogs in each case had been some days paired, and at the time of the experiment were nearly ready to spawn; next, that the seminal fluid used was obtained from the male paired with the female from which the eggs were taken; further, that the condition of the specimen of fluid used was correctly ascertained; and lastly, that the ova were placed in flat dishes, under precisely similar circumstances, with similar quantities of water, repeatedly changed. Two sets of experiments were made at the same time.

Set M. April 4, 1850. Atmosphere 60° Fahr.

The seminal fluid employed, mixed with an equal quantity of water, was placed on a *single*, and caught on a double filter paper, and the clear fluid that passed was then examined with the microscope. The fluid that had traversed the three filters was almost completely deprived of spermatozoa; as, after many very careful examinations, both

of drops as they passed the last filter, and of portions from the capsule it was caught in, there was only one instance of the presence of spermatozoa. In this I saw *two*, but perfectly motionless. The fluid that passed through the *first* or top filter, I had reason to suspect was contaminated by a small quantity having travelled over the sides of the filter. I knew also, that a few spermatozoa always penetrate through a single filter, or rather perhaps are carried through by the fluid. Accordingly, I detected several spermatozoa in this portion. The fluid that remained in the interior of this filter abounded with very active ones. It was not employed until fifty-three minutes after it had been procured from the Frog.

No. 1. *Seventy ova* were passed on a dry surface, and a portion of the fluid which had traversed three filters was poured carefully over them, and water was then added.

In *four hours and twenty-five minutes* I found *one ovum* partially impregnated, and the yelks of others were somewhat shrunk, and a little irregular, an appearance frequently seen in ova that have not been impregnated. Not a single ovum, however, was fruitful.

No. 2. *One hundred and twenty-seven ova* were shed into water on the second of the three filters, which still retained a portion of the fluid from the first, and in which I had found a few spermatozoa. At *four hours and fifty minutes* several of the ova had begun to be divided, and out of this set of eggs *sixteen embryos* were produced.

No. 3. *One hundred and sixty-three ova* were passed into water on the topmost of the three filters, and *four hours and fifty minutes afterwards* a very large proportion of them had become segmented, as was expected, although from the circumstance of the seminal fluid having been more than one hour mixed with water before it was employed, the number was not so great as usual. But it was not entirely due to this cause. Many of the ova had been injured before impregnation, and these became irregular and pear-shaped. At the end of twelve days *forty-nine* well-developed embryos had been formed.

Set N. April 4, 1850.

Four filters were now used instead of three, the seminal fluid being obtained and mixed as before. The fluid which had passed through the whole of these filters, contained not a trace of spermatozoa or of the nuclei of cells. That which had passed through two only still gave an occasional perfectly motionless spermatozoon, but not a single one in motion; the fluid from the uppermost or first filter, as in *Set* M, still swarmed with myriads of active spermatozoa. It was thus proved that the filtration was complete.

No. 1. *One hundred and thirty-one ova* were passed on a dry surface, and a portion of the fluid which had traversed the four filters was poured over them, and water was then added. But not a single ovum gave any sign of having been impregnated, not one became segmented, nor was a single embryo produced. The ova became slightly irregular, shrunken, and depressed at parts of the yelk, a condition which, as I had

noticed this in other ova, I was inclined to attribute to some normal change in the yelk itself, perhaps of an imbibing or endosmic character.

No. 2. *One hundred and ninety-seven ova* were shed into water mixed with the remaining portion of fluid which had passed through the four filters, but not a single egg gave even a trace of segmentation. Many of the yelks had the same peculiarly irregular outline as in No. 1. These two experiments I regarded as a satisfactory proof that it is not the fluid portion of the semen which impregnates.

No. 3. *Two hundred and four ova* were passed into water upon the third filter, already immersed in it, and the fluid on which showed an occasional spermatozoon. I was unable to detect any impregnated ova in this experiment, but, as the result showed, a few had been affected, as *four embryos* were produced.

No. 4. *Three hundred and seventy-one ova* were passed into water upon the first or topmost of the four filters, and which had already been placed in the water. At *four hours and thirty minutes*, almost every yelk had become segmented. The change had occurred some length of time before this, as the second or crucial segmentation was commenced. This experiment seemed to be a most direct and conclusive proof of the agency of the spermatozoa. At the end of four days almost the whole of the eggs were producing embryos, many of which were advanced to the *fourth period of development*. *One hundred and twenty-seven* became fully formed and vigorous, besides nearly as many more which did not complete their changes, from an accidental cause.

Before these concluding experiments were made, I had already, in March last, repeated the preceding; but, as the filtration was less perfect, have thought it unnecessary to give them in detail; they agreed however in the results. The whole have confirmed in the fullest manner the experiments first made, and have proved, as I trust, satisfactorily that the spermatozoa alone are those parts of the semen which effect the impregnation of the ovum. Having repeated the filtration in five separate sets of experiments, on different occasions, and with exactly the same general results, I can no longer entertain any doubt of the direct agency of the spermatozoa. The conclusion, I think, is rendered certain by facts now shown, which escaped the notice of Spallanzani, and of Prevost and Dumas. Segmentation of the yelk takes place earlier when impregnation is effected by a large, than when occasioned by a very small number of spermatozoa, the temperature of the surrounding medium, and all other circumstances, being alike in the two cases, as in the experiments *Set* A as compared with *Set* B (p. 190). This fact is supported by another, equally significant. When only a very small number of spermatozoa exist in the fluid, then the remarkable result of partial impregnation often takes place, and the ova are unproductive. On the other hand, when spermatozoa are supplied in full abundance to the ova, not only does segmentation of the yelks take place more rapidly, but also more extensively, and almost every ovum produces an embryo.

With regard to the liquor seminis, it seems equally decisive that this portion of

the seminal fluid *does not* effect impregnation. Wagner and Leuckardt* have justly remarked, that it is almost impossible that the *liquor seminis* can have any action on ova which are expelled into water before the semen is ejected by the male, as in the case of frogs and fishes; and it is worthy of note, that in the experiments now detailed not a single ovum was either *completely* or *partially* impregnated when immersed in water mixed only with the liquor seminis, obtained through filtration; nor even when the ova were carefully bathed, as they passed from the body of the Frog, and before they had been brought into contact with water, with the filtered fluid from which the spermatozoa had been completely separated, as in *Set* N, No. 1, or even when the fluid still contained a very few dead and perfectly motionless spermatozoa. Yet this fluid can hardly be regarded as entirely without use, although it now appears to be of very secondary consequence. When the ova were placed in water with which only the *liquor seminis* had been mixed, the yelks became contracted exactly as is often the case in the unimpregnated ovum. Whatever may be the nature of this fluid, it does not appear to be essential to the conveyance of the structural peculiarities of the male parent to the offspring. These appear to be communicated by the spermatozoa alone, as not only did the ova that were impregnated by spermatozoa from the filter paper, as in *Set* N, No. 4, become segmented quickly, but the embryos produced from them came forth with all the usual characters of tadpoles, and have passed, or are now passing (June 20) through their stages of growth as perfectly and as quickly as others which have been produced in the natural haunts of the species through the mutual concurrence of both sexes. Thus the liquor seminis does not even hasten the course of development of the young. Neither does it accelerate that of fecundation, either through direct imbibition or from becoming a solvent to the bodies of the spermatozoa; as we have seen that segmentation of the yelk takes place most quickly in proportion to the number of spermatozoa, within certain limits, in contact with the ovum. And such also is the case in a state of nature.

These facts appear to give that *direct negative* and refutation to the hypothesis of the immediate agency of the liquor seminis in impregnation which Wagner and Leuckardt† remark it has not hitherto met with; and they lead to the supposition that one of the chief uses of the fluid is merely that of a vehicle through which the spermatozoa are more readily brought into contact with the ova. Possibly it may bear that relation to the spermatozoa in the viviparous vertebrata, in which it chiefly occurs, which the fluid medium into which the ova of Amphibia and Fishes are expelled, bears to the spermatozoa in those classes. This view may derive some support from the fact that the liquor seminis has recently been shown by chemical analysis to consist chiefly of a thin solution of mucus, with small quantities of chloride of sodium and phosphates and sulphates of the alkalies‡.

* Cyclopædia of Anatomy and Physiology, vol. iv. "Semen," part xxxiv. January 1849, p. 507.

† *Loc. cit.*, p. 507. ‡ *Id.*

5. NATURE OF THE AGENCY OF THE SPERMATOZOA.

Having obtained full evidence by direct experiment that impregnation is effected through means of the spermatozoa, we have now to inquire as to the manner in which it is induced by them, and as to the nature of the agency they exert. Spermatozoa have been found adhering to the surface of the impregnated ovum by Barry, Bischoff, Pouchet and others, in the Mammalia; as they were long ago seen by Prevost and Dumas on the ovum of the Amphibia; and since by Siebold, Kölliker, myself and others in the Invertebrata. They have been constantly present in those experiments on artificial impregnation which I have now detailed, in which the yelks became segmented after the egg had been in contact with seminal fluid, or with the filter paper used to remove them from the liquor sanguinis; but they have not been detected on ova which did not undergo the cleavage of the yelk, or which had been immersed only in fluid separated during filtration. Whenever present in fluid in which ova have become impregnated, the spermatozoa have always been found in motion, until after they have become attached to the surface of the ovum, when their motion has soon ceased. In the *Lissotritons*, in the few experiments I have made on this division of the Amphibia, I have seen the motion continue for a long time after they have been in contact with ova. This leads to the supposition that a vibratile condition or power of motion is in some way essential to their power to effect impregnation; notwithstanding that, as Wagner and Leuckardt have remarked*, no movements have as yet been perceived in the spermatozoa of the *Isopoda* and *Amphipoda*. If this vibratile condition be essential to their function, then the length of time which it is continued may be of importance.

Duration of Motive Power in Spermatozoa.—Spallanzani found that water mixed with but a small quantity of seminal fluid of the Frog retained the property of impregnating ova longer than pure semen†. When inclosed in a glass tube, the semen of the Toad was not impaired at the end of six hours, but was useless at the end of nine‡; while a small quantity from the Frog, mixed with water and preserved at a temperature of about 40° Fahr.§, was still efficient at the end of thirty-five hours. Results obtained by myself have fallen short of this extended period, even when the influence of temperature has been attended to. The difference of result may to some extent be accounted for in the condition of the fluid, and in the way in which it has been obtained. Spallanzani says he obtained it both from the vesiculæ seminales and the testes after opening the body. It is probable therefore that a large part of what he procured had not arrived at maturity, and instead of consisting almost entirely of active spermatozoa, as when it is obtained by compression of the body, the

* *Loc. cit.*, p. 503. † Dissertations, vol. ii. p. 193. ‡ *Id.* p. 168.

§ It may be well here to mention, that for the purpose of more easily comparing the observations recorded by Spallanzani, and Prevost and Dumas, with the results obtained by myself, I have, throughout this paper, reduced the data given by them to the scale of Fahrenheit, employed by myself; the scale used by Spallanzani being that of Reaumur, and by Prevost and Dumas the Centigrade.

mode adopted in my experiments, it included a large proportion of developmental cells from which the spermatozoa escaped at longer or shorter periods after the fluid had been mixed with water, or had been retained for some time out of the body. I have very rarely found the seminal fluid of *Rana temporaria* obtained in the way stated, and at a temperature of about 50° FAHR., retain any impregnating influence for more than four or five hours. Thus, after mixing it with an equal proportion of water, very many of the spermatozoa have soon become motionless, and in less than two hours a moderate proportion only have continued active. At three hours there have been still fewer moving; while at four hours the great majority of them have exhibited most unequivocal signs of lost vitality, being either extended at length or coiled on themselves (Plate XIV. fig. 8 *c*), as they usually appear when motionless, and adherent to the surface of ova. If any, at this length of time, have been still moving in the fluid, they have been few in number, and their motions exceedingly feeble. Occasionally I have detected others, at this lapse of time, in the act of escaping from the cells (fig. 8 *a* and *b*), and these have always been the most energetic in their movements immediately after their liberation. Further, I have noticed that in those specimens of fluid which have contained most developmental cells, the spermatozoa have been longest in a state of activity.

The following have been the results of observations on spermatozoa attached to the surface of ova, or contained in the water in which ova were immersed. At *three-quarters of an hour* after mixing *recently obtained* seminal fluid with the water and ova, vibratile spermatozoa have continued to be exceedingly abundant and in a state of great activity. *At one hour and a quarter* there were still an abundance in motion, but many were now perfectly motionless, and apparently dead. At *one hour and a half* I was not able to detect any movement in even a single spermatozoon out of a vast abundance which adhered to the surface of the gelatinous coverings of the ova, although I sought for this very carefully. Neither could I detect even the slightest indication of the spermatozoa having penetrated into these coverings, either near the surface or in the vicinity of the thicker envelope, which I regard as the *chorion*, and which immediately covers the *vitelline membrane*. After a lapse of some time all the appearance of spermatozoa on the exterior of the envelopes ceased. The longest period, after contact with spermatic fluid in water, at which I have hitherto been able to recognize these bodies on the surface of the frog's egg has been *six hours and one or two minutes*, and about half an hour after segmentation of the yelk had commenced. This was on ova impregnated artificially, on the 14th of March, at a temperature of the atmosphere of the room of 54°·5 FAHR. and 53°·5 of the water employed. A few motionless spermatozoa were then still found on the surface, but most of them appeared to be becoming disintegrated. The surface of the egg-envelope was then covered at places with numerous small granules, possibly the remains of spermatozoa which had disappeared.

A somewhat similar result has ensued when spermatozoa have been *two hours* mixed

with water before ova were passed into it. At *five minutes* after immersion of these ova, I have found large quantities of spermatozoa already adhering to the surface of their then expanding envelopes. But many of them have already been coiled on themselves, and were perfectly motionless. The water still contained very many disseminated through every part of it, but most of them, with few exceptions, have appeared to be rigid, and to have become enlarged in diameter, but not increased in length. This change has appeared to be due to the hygroscopic nature of these bodies, as formerly pointed out by Siebold*. Possibly this nature may have some reference to impregnation. Repeated observations lead me to believe that, in whatever way the spermatozoa are concerned in impregnation, they do not penetrate bodily into the ovum, but merely adhere to the surface.

Prevost and Dumas concluded† from their investigations, that the spermatozoa of the Triton and Frog do penetrate into the envelope of the egg; and they state that they had fecundated ova taken from the ducts of the Triton, and after the lapse of three hours, having first carefully washed them to remove all that were merely adhering to the surface, have made sections of the envelopes of the egg, and, with the aid of the microscope, have found living spermatozoa still struggling within. Their words are—"Une grande quantité d'animalcules encore mouvans, et qui semblaient se débattre dans cette espèce de gelée où ils se trouvaient emprisonnés. On en voyait partout même au contact des membranes de l'œuf." Further, that they had repeated this experiment on the ova of the Frog, and found the envelope penetrated in like manner with spermatozoa, still moving, but not changing place. I regret much that my investigations do not enable me to confirm these observations, which seem to me to be due to the circumstance of these physiologists having regarded the objects on the surface as being in the interior. I have many times sought for spermatozoa within the substance of the egg-envelope of the Frog, at different periods between that of first contact with impregnating fluid and the time when cleavage of the yelk has commenced, and have constantly found them on the surface, but have never, even in a single instance, observed any appearance of them in the substance of the envelope, nor anything which induced me to suspect that they penetrate bodily into it. They have been present on the surface, and adherent to it, even from within a few seconds after contact, to so late as the sixth hour, but have usually been motionless; and most of them have had the caudal portion folded back on the body. I was led to make these observations on the egg of the Frog,—before I was aware of MM. Prevost and Dumas' views,—from the circumstance of Dr. Martin Barry having mentioned‡ that an orifice or fissure exists in the thick investing membrane of the ovum of the Rabbit, through which, at the time of impregnation, he believed the spermatozoon to enter. All the observations I have been able to make on the ovum of the Frog, both microscopically and experimentally, are opposed to the belief in the existence of any perfo-

* Müller's Archiv, 1836.

† *Loc. cit.*, vol. ii. p. 133.

‡ Philosophical Transactions, 1840, p. 535.

ration either before or at the time of impregnation. With regard to the ovum of the Tritons, I have recently made the following observations, since becoming acquainted with the views of the authors named.

A female *Lissotriton punctatus*, obtained on the 17th of May, produced several ova on the morning of the 19th. Cleavage of the yelk (which, I may remark, was entirely overlooked by Rusconi* in his account of the Newts) commenced in two of these ova at the expiration of eight hours, the temperature during the period having ranged from 56° Fahr. to 62° Fahr. On examining these ova very carefully about an hour before the cleavage commenced, there were what I regarded as portions of the bodies of spermatozoa on the surface, but certainly no traces of any in the interior. While engaged in this examination the same female produced another egg, which she inclosed as usual in a folded leaf. On this specimen, examined at the end of half an hour, I could not detect any spermatozoa on the surface, which led me to imagine that it had not been impregnated, a supposition which ultimately proved to be correct, as no segmentation of the yelk took place in it. Some time after this, the temperature of the atmosphere being 62° Fahr., I saw the same newt enclosing another egg in a leaf. This I immediately removed for examination, and thinking that this, like the previously deposited egg, had not been impregnated, no traces of spermatozoa being found on its surface, I placed it for about a minute in a small capsule filled with water, into which a quantity of fluid had just been expressed from a male that had been kept separate from the female. The fluid on examination was found to be composed almost entirely of very active spermatozoa. The egg was examined three minutes after immersion, and scarcely five minutes after it had been laid, and multitudes of spermatozoa were then seen adhering to its surface. Most of them were still vibrating rapidly, while others were motionless. But although I was able to distinguish every part of these bodies, I could not detect any in the act of penetrating, or which had already penetrated into the substance of the envelope, and most certainly not one was imbedded in the interior. Neither were there any in contact with the yelk-membrane, or in the yelk-chamber of the envelope.

The egg of the Newt is peculiarly fitted for an examination of this kind, from the fact of the existence of this yelk-chamber, or space in the interior of the envelope. This is formed by the gelatinous covering which the egg gains in the oviduct imbibing fluid by endosmose and becoming expanded immediately it comes into contact with water, when the inner layer separates from the vitellary membrane, with which it has been in contact within the duct; and as the outer layers more and more expand, the yelk, covered only by the vitellary membrane, is left free in a large cavity in the interior, surrounded by a thin fluid. The spermatozoa of the Newts, as is well known, are of large size, and are easily recognized; so that in the event of their having penetrated the egg-covering before it leaves the duct, or at the moment of its expansion, or after the chamber has been formed in it, they can hardly escape observation.

* Amours des Salamandres Aquatiques, 4to. Milan, 1821.

I preserved this egg confined to one spot in a minute glass capsule, and in exactly the same position beneath the microscope, for forty-eight hours. During the first three quarters of an hour many of the spermatozoa on its surface exhibited as vivid motions as at first, but still adhered to the same parts, and had not, so far as I could perceive, changed their posture or their place in the least, or had penetrated in the slightest degree into the envelope. At the end of twelve hours I found that the yelk had undergone the usual process of cleavage, which, at that time, had already been advanced to the stage of coarse granulation of the surface, a fact which proved most distinctly that this egg had been impregnated. Spermatozoa were still distinctly recognized over the whole surface of the envelope, but their motions had now ceased. On the following morning, May 20th, the changes were found to have proceeded uninterruptedly, as the yelk was then finely granulated over its whole surface. At a little later period, the *end of twenty-four hours*, a few spermatozoa were still adhering to the surface of the envelope, but the whole were perfectly motionless, and many had evidently disappeared. Still, not one could be detected in the substance or in the chamber of the envelope. At *twenty-eight hours* the granulation of the yelk was nearly completed, and its surface was becoming smooth, and there were still a very few motionless spermatozoa on the exterior of the envelope. At the end of *forty-eight hours*, May 21st, I was still able to recognize the bodies of several spermatozoa which had not yet disappeared, but which had become very indistinct, as if in a state of diffluence. At the end of *sixty hours* I could no longer detect any trace of them. The egg that was the subject of these observations proceeded regularly in its changes, and ultimately produced the embryo; all the stages of which I have traced and delineated for future communication to the Royal Society.

Subsequently to these observations I saw ova passed by another female, *Lissotriton palmipes*, and on submitting these to the same close examination as the above, within five minutes after their production, I again found what I regarded as the remains of spermatozoa on the surface of the egg-covering, but not a trace of any in the interior or in the vicinity of the yelk.

Endosmosis of the envelopes during impregnation.—But although the facts now mentioned are so opposed to the view that the spermatozoa penetrate bodily into the ovum, it is due to the distinguished observers to whom I have referred to enter somewhat more fully into the questions which their observations involve; and while I am free to admit the possibility of mistake or oversight on my part, to mention the details of some experiments made expressly with the view to ascertain whether the envelopes of the ovum of the Frog are permeable in any part to solid particles of matter; or whether there exists any orifice in them by which such particles can enter. It is well known that during the transit of the ovum through the oviduct the vitellary membrane becomes invested with a thick gelatinous covering, the first thick layer of which may be regarded as the rudimentary *chorion*, and perhaps may be analogous in its function, in some respects, as it seems to be in its place and mode of origin, to

the albuminous investment of the ovum of the Rabbit. I cannot, with Rusconi*, regard this envelope of the Frog's egg as being merely a mechanical protection during the process of development. It is formed of cells with distinct nuclei, and from what I shall presently mention, seems to be essential to the ovum at the commencement of the changes, and to be intimately connected with the act of impregnation. Rusconi deprived the ova of the green aquatic frog, ? *Rana esculenta*, of their gelatinous envelopes at a period subsequent to impregnation, and found that they passed through their changes as well as when covered by them; and he thence concluded that the envelope is of no use further than to protect the egg from the injury it might receive through mechanical disturbance, "des petits chocs qui pourroient nuire à son developpement†." Certainly it affords this protection to the germ, but to conclude that this is its sole office appears to be somewhat premature. I have found that it is almost impossible to remove this envelope from the Frog's egg at the moment of deposition, or even during the first few minutes after submersion, and before it has become expanded by imbibition of fluid; although it may be removed without much difficulty from the egg of the Newt, the yelk of which, in the vitelline membrane, lies free and unattached in its interior. But some time after the expansion has taken place I have myself found that the frog's egg may be deprived of a large portion of this covering, and yet produce an embryo equally well as if it had remained protected. On the other hand, one most important function of this investment seems to be indicated in the following facts. Spallanzani found that ova of the Frog deprived of their envelopes before contact with the male influence, were not impregnated; and further, that ova taken directly from the ovaria, are not susceptible of impregnation‡.

A remarkable fact which I noticed, at a time when I was not fully aware of its interest and importance, enables me to confirm this observation. I captured a pair of frogs, the female of which, a short time after they were in my possession, had a large hernia formed by a protrusion of part of the great oviduct through an accidental wound in the posterior part of the right side of the body, and in consequence of which she was unable to deposit her ova. This wound had been received before the union of the sexes, but the hernia was formed afterwards, during the passing of the ova from the ovaria. The result of this was, that when some of the ova had passed into that part of the duct which protruded through the wound, the sac formed by it was constricted, and became so enlarged by the expansion of the egg-envelopes, that the remainder of the ova were prevented from entering it. On opening the abdomen of the frog after death, I found that a very large proportion of the ova which had left the ovarium on that side of the body, were lying in the cavity of the peritonæum, among the viscera, being entirely prevented from entering the duct, which was filled throughout its whole extent, to its very orifice, with eggs which had already entered, and were prevented from passing on. On the left side of the body the ova had

* *Loc. cit.*, p. 8. † *Loc. cit.*, p. 9. ‡ Dissertations, &c., ii. 152, 3.

also quitted the ovarium, but the whole on that side had passed into the oviduct in the usual way. The eggs found in the cavity of the body consisted only of yelk-masses in their vitelline membranes. I immediately placed some of these eggs in water, with seminal fluid obtained from the male with which this female had been paired; but not a single egg became impregnated, or gave afterwards any sign of formation of the embryo. I had some hesitation in regarding this experiment as quite conclusive,—that impregnation cannot take place before the egg has gained its gelatinous envelope, and consequently while it is still within, or has but just escaped from the ovary,—from the possibility that these eggs might have been for some time in the cavity of the body, and that some change might have been induced in them through long detention. In so far, however, as that this was in accordance with Spallanzani's experiment, it seemed to point to the nature and importance of the covering which the egg gains in the oviduct.

Since my attention has been more particularly directed to this point of investigation, I have repeated the experiment on the ova of the Newt, *Lissotriton palmipes*, with precisely similar results. I opened the body of a female with great care (after dividing the spinal cord through the medulla oblongata), for the purpose of obtaining ova from the oviducts, for artificial impregnation, and immediately saw that a number of ova were free in the cavity of the abdomen, and were in the course of being transferred to the entrance of the tubes, as stated in the first part of this paper. These ova, like those which had recently escaped from the ovarium in the Frog, were without any other covering than their vitelline membranes; most certainly I was unable to detect any other, and they were so delicate that it was with difficulty they were removed into water to which fluid from the male had been added. But although uninjured in the removal, and in every way carefully treated, not one gave any sign of cleavage of the yelk, which, as I have before stated, I have constantly found take place in the impregnated ova of newts as well as of frogs, although the fact of its occurrence was overlooked by Rusconi; not one egg afterwards produced the embryo. Thus then it seems fair to conclude that the egg in the *Amphibia* is not fitted for impregnation until after it has entered the oviduct and acquired its gelatinous covering.

I have already shown that there is a remarkable coincidence between the rate of expansion of the gelatinous covering, immediately after the egg is placed in water, and the susceptibility of the egg to become impregnated; and that in proportion as the covering becomes enlarged and distended by imbibition of water, the susceptibility of the egg becomes diminished; until at the end of about half an hour it is almost completely lost, at which time the rate of expansion of the envelope is also greatly lessened, and the envelope itself has attained to more than two-thirds its future diameter. Now Spallanzani found that the susceptibility of the ovum, when immersed in water, had ceased at the end of fifteen minutes, at which time the envelope is considerably enlarged. Prevost and Dumas also observed that the expansion of

the envelope is greatest during the first three hours, and rightly regarded the occurrence as connected with impregnation, and with this opinion made experiments to test their views. They placed ova taken from the oviducts in ink, and found the envelopes blackened with the imbibed fluid*; but they remark—"bientôt cette imbibition s'est arrêtée à cause de la reaction chimique de l'encre qui coagulait la matière muqueuse." Afterwards they employed the blood of the Frog mixed with water, and found the envelope deeply reddened when immersed in it; and thence concluded that the envelope in its normal condition admits of the entrance into it of solid particles of matter held in suspension in the fluid. But each of these experiments appears to be open to a different explanation. It is probable that the chemical action of the ink, by altering the condition of the envelope, allowed of the admission into it of solid particles only in proportion to the change in the tissue; and that the colour given to the envelope by frog's blood was due to particles of colouring matter which adhered to the surface, rather than to the admission of these into the substance of the tissue. This conclusion is founded on the following trials.

The imbibition of water by the covering of the egg being so distinctly marked, I had intended, like the authors mentioned, to endeavour to ascertain whether coloured water could be as readily absorbed as pure water. Through accident, however, I omitted to put this question to the test until late in the season of last year, and after the whole of my frogs had spawned. But having placed several ova in rectified spirit for future examination, at the moment of passing them from the body of a frog, I determined to test the result of the immersion of these in coloured fluid, although well aware of the correct objection that would be made, that the experiment must of necessity be inconclusive. I put some of these into a solution of carmine in water, and watched the result. The envelope, which, while the egg was in spirit, was white, opaque, and adhered closely around the yelk membrane, began to imbibe and expand the instant it was placed in the solution; and at the expiration of an hour there seemed reason to believe that the trial had succeeded. The envelope was much enlarged, and the fluid had penetrated into it, carrying with it some colouring matter; as on carefully washing the surface repeatedly in clean water, to remove the deposit on the exterior, the substance of the interior was seen to be coloured, and it was evident that the colouring matter had penetrated as far as the deepest or thick layer of the envelope. This result appeared to favour the view that the spermatozoon enters the ovum. When the ova were again examined at the end of the third day's immersion, they were of a deep red; the deepest stratum of colour being then between the vitelline membrane and the thick or innermost layer of the envelope. The entire egg presented the appearance of a globule or bead of red glass, with a dark red centre, surrounded by a lighter-coloured halo. The eggs were then thoroughly washed and placed in clean water. At the end of six hours part of the colouring matter had again been removed from the interior, and the eggs were of a less deep hue, and the

* *Loc. cit.*, ii. p. 132.

water they had been immersed in was coloured. I then again removed them to clear water. At the end of sixteen hours they had parted with more colour, but were still red, more especially between the inner portion of the envelope and the vitelline membrane, and the water had again acquired a red hue, thus showing that both endosmose and exosmose must have taken place.

As it might fairly be objected that these ova, changed by immersion in spirit, were unfitted for experiment, I made trial with others which had not been impregnated, and being infertile, had remained in water many days without giving signs of decay. When these were placed in the carmine solution, their envelopes became as deeply and thoroughly imbued with colouring matter throughout their whole substance as in the former; and when placed in clear water they parted as readily with a portion of it, so that it was evident that whenever the density of the fluid in which these dead and infertile ova were immersed, was altered, a change by endosmose or exosmose immediately took place in the fluid retained mechanically in their tissues. To this cause, perhaps, may be ascribed the colouring of the ova in Prevost and Dumas's first experiment with ink, while other experiments, which I shall mention, made on living and impregnated ova, lead me to regard the colour in the experiment with frog's blood as merely the result of adhesion of colouring matter to the surface.

The immediate objects I had now in view were, to learn whether impregnation is effected by any direct and palpable infiltration of seminal matter through the envelopes of the ovum;—whether the admixture of other matters with the seminal fluid will prevent or arrest impregnation;—and whether the spermatozoa collected on a filter paper, and then placed with this in a fluid of great density, are as efficient as in clear water.

With these views, I prepared a very dense solution of carmine pigment in water, and added parts of this to small quantities of water with ova, either before the seminal fluid was mixed with the water, or immediately afterwards, and I expected the results to show whether any solid particles, held in suspension in the fluid, passed through the envelopes. The previous trials had shown that solid particles do pass through the *dead* tissue, but it was doubtful whether the like result would occur in the living.

Carmine Experiments.—Set O. March 13, 1850. Atmosphere 53° Fahr.

No. 1. *Eleven unimpregnated ova* were passed into water mixed with carmine.

The envelopes became as fully expanded, and imbibed fluid as freely as in the impregnated ova, and acquired a red tint; but much of the colour was due to the deposition of granules of matter on the surface, while I was unable to detect any similar granules within their texture. On the contrary, on removing part of the surface of the envelopes, the interior, although slightly reddened, exhibited an uniform appearance.

No. 2. *Thirty ova* were passed into water that had been mixed with seminal fluid, and immediately *afterwards* a solution of carmine was also added.

Twenty-six of these ova became impregnated and produced embryos; thus showing that impregnation takes place very quickly, and is not prevented by the addition of a dense colouring fluid, added *after contact* with the impregnating fluid.

No. 3. *Forty-one ova* were passed into a solution of carmine in water which had been mixed with seminal fluid immediately *before* the passing of the ova.

Thirty-three of these ova also produced embryos. It was evident, therefore, that when seminal fluid is freely mixed with a dense medium that holds solid particles of matter in suspension, the spermatozoa are not necessarily prevented from effecting impregnation of the ova. Thus the ova of the Frog, although usually deposited in slow-running or clear still water, may be deposited even in slightly turbid water without impediment to the natural process of impregnation, as the water and spermatozoa may be brought into contact with the ova at the same instant.

No. 4. *Thirty ova* were passed into water mixed with fluid that had been almost completely deprived of spermatozoa by filtration.

Only *one ovum* exhibited any signs of impregnation, but not a single embryo was produced.

No. 5. About *two hundred and twelve ova* were passed into a dense solution of carmine and water in which the filter paper with spermatozoa, separated from the fluid employed in No. 4, had already been placed, and the water and ova were then freely agitated together.

The result of this experiment was very marked. Only a few of these ova became segmented, and the change proceeded much slower in them than in the ova of experiments Nos. 2 and 3. At the end of twelve days only *five embryos* had been produced. Thus a dense solution of carmine, applied to the spermatozoa *before* they are brought into contact with ova, may have the effect of preventing impregnation, apparently by operating as a mechanical impediment. These ova, excepting only a few removed for the following experiment, No. 6, which were taken from the mass as stated, were allowed to remain in the carmine for twenty-four hours before they were placed in clear water.

No. 6. *Forty ova* taken from the last experiment were removed to clear water at the end of one hour and a quarter, having first been thoroughly washed. The result was as decided as in No. 5. *Only two embryos* were formed; so that there was further reason to believe that impregnation takes place very quickly, and that the result in No. 5 was not entirely due to long continuance in the solution, but to some impediment at the time of contact.

No. 7. A thick solution of carmine was mixed with seminal fluid and water, and *three minutes afterwards* a mass of ova were passed into it.

This experiment was similar to No. 3, excepting only that the solution of carmine was much more dense, and the ova were not passed until three minutes after the fluids had been mixed. There was a marked difference in the result. Only a few of these eggs became segmented, and only *eight* out of a large mass produced embryos.

But there were several eggs that appeared to have been *partially impregnated*, the whole of which were abortive. *Partial impregnation*, as before stated, is shown in a very imperfect cleavage of the yelk, sometimes on one surface only, and sometimes complete as regards one half of the yelk, but imperfect or irregular in the other.

No. 8. *Forty-two ova* from the last experiment, No. 7, were removed from the carmine at the end of *thirty seconds*, and were immediately well washed to get rid of the adhering spermatozoa and granules of colouring matter. Not one of these ova produced an embryo, but several had become *partially impregnated*.

These experiments were made in the middle of March, when the season was unusually cold, and the mean lowest temperature of the room during twelve days was only 43° Fahr., and the mean highest 47° Fahr.; at a higher temperature the results, I have little doubt, would have been more favourable. The eggs had been impregnated however when the temperature, during the first twelve hours, was 55° Fahr., so that the question respecting the infiltration of solid matter with the water absorbed by the envelopes of the eggs was not affected.

About *four hundred and twenty* eggs were employed in this set of experiments; yet I could not detect any granules of the colouring matter of carmine held in suspension, and of dimensions equal to those of the spermatozoa, which had passed into the tissue of the envelopes of the eggs, although they had become tinged by the colouring matter in combination with the water. Abundance of granules of colouring matter of most minute size, and not more than one-third the diameter of the spermatozoa of the Frog seen beside them, adhered to the surface of the envelopes, and it was to these chiefly that the red colour of the whole was due. Every part of the envelope exhibited the same uniform appearance, the granules being pretty equally distributed over the surface, and the suffusion of colour was uniform in the interior. These facts appeared to be conclusive with reference to the question of the presumed existence of a fissure or perforation through the coverings of the egg of the Frog before, or at the moment of fecundation, as is supposed to exist in the ovum of the Rabbit. I have not been able to detect any appearance of orifice or fissure in the egg of the Frog-envelopes, and the course of which, if such really exists, would no doubt be indicated by some deposition of the colouring matter of the carmine, to a greater or less extent, in its tract. The result of these experiments was thus most unfavourable to the belief that the spermatozoa penetrate bodily through the membranes of the ovum; and to that of the supposed existence of a special opening in these membranes for their admission.

I ought now, however, to mention one experiment that seemed to favour the opinion that the spermatozoon enters the ovum. I had taken several ova, together with the oviducts into which they had passed, from the body of a *Lissotriton palmipes*, and others from that of *Triton palustris*, for the purpose of artificial impregnation. Some of these I pressed from the oviducts into a very clear solution of carmine, taken from a solution which had remained undisturbed for nearly a fortnight, so that the granules

in suspension had subsided, and only the colouring matter actually combined with the water gave it its red hue. At the end of half an hour I removed the ova from the solution to clear water for examination, and then found that the interior of the envelope was coloured by the water which had entered, but that the greater portion of the colouring matter had been arrested and separated at its entrance and adhered to the surface. One ovum of *Lissotriton palmipes*, however, to my great surprise, had a little dense mass of colour deposited at one point only of the dark surface of the ovum, not merely within the envelope or its chamber, but actually beneath the vitelline membrane, between it and the yelk, as was distinctly proved by turning the egg on one side and viewing it in profile. Not one of the other eggs, placed in the solution, either of the *Triton* or *Lissotriton*, showed any appearance like this; so that while I am debarred from expressing a decided opinion that the spermatozoon does not enter the ovum, I can only regard the appearance mentioned as entirely accidental, and not as a normal occurrence; but as resulting, perhaps, from some minute puncture or other accident during the removal of the eggs from the body or the oviduct.

But in order, if possible, to remove another source of doubt, it seemed necessary to make some trial with the colouring material employed by Prevost and Dumas in their experiments; and some further examination of that used in my own; and to ascertain whether any solid particles or granules of matter, held in suspension in ink or in carmine, and equal in size to the spermatozoa of the Frog or the Newt, can be passed through the filter, or can be separated from the fluid portion by filtration, like the spermatozoa, when precisely the same mode is followed, and the same means and same description and number of filter-papers are employed, as in the filtration of the seminal fluid. The solution of these questions it was evident must tend to confirm or to unsettle the previous conclusions. I first tried *ink*, and used a part of the identical filtering-paper employed to separate the spermatozoa. The ink passed quickly and freely through three filters without losing any of its intense black colour, and carried with it only a very few extremely minute granules, much smaller in size than the spermatozoa of the Frog; so that it seemed fair to conclude that the colour imbibed by the ova from *ink*, in MM. Prevost and Dumas' experiment, was due to the admission of the chemically combined colours of the fluid, and not to an admission into the texture of the egg-envelopes of solid particles held merely in suspension in the fluid. Consequently this experiment seemed to negative the supposition that, from the fact of the interior of the egg-covering becoming blackened, solid particles of matter, equal in size to the spermatozoa, must have penetrated into the envelope during its expansion; and there seemed less reason to believe that the spermatozoa,—bodies very much larger than the ink-granules,—could enter it. *Carmine* was then tried. A solution of this colour could scarcely be made to pass through even a single filter. This seemed to be due chiefly to the fact that the greater proportion of the colouring matter of the carmine used (the water colour pigment of artists) was combined with gum and an earthy base, and consequently most of the colour was in

suspension rather than in chemical combination. When placed on a single filter, the solution passed through with extreme difficulty and slowness. When a microscopic drop of the fluid so passed was examined with a power of three hundred diameters, it was found to contain a large quantity of granules suspended in clear fluid. When made to pass, but with still greater difficulty, through a second filter, it still contained a quantity of minute granules, but each *less than one-half the diameter* of the spermatozoon. It is *possible*, therefore, that some extremely minute granules may penetrate into the texture of the envelope, formed as it is of aggregations of cells; but it seems to be very improbable that any of the larger-sized objects, such as the spermatozoa, can enter: and it is even much more improbable, that if the chief colour of the ova in my experiments was due, as I believe, to granules of carmine on the surface, and not in the interior of the ova, that in MM. Prevost and Dumas' experiments with frog's blood, the ova should have become reddened by the admission of particles of this into their interior, since it need scarcely be mentioned that the colour of the blood is due only to the particles suspended in it; and MM. Prevost and Dumas remark, that they were not able to detect any blood-globules on the surface. To what else, then, than to these, or to their broken-down particles, could the reddened colour of the ova in their experiments be due?

The conclusion, then, to which I am led by these experiments is, that although the envelopes of the egg imbibe coloured fluid, they do so less easily than when the fluid is not coloured, unless it is in chemical combination; and although atoms of solid matter, very much smaller than the spermatozoa, may possibly be carried by infiltration into the texture of the egg-envelope by the act of endosmose during its expansion, it appears to be extremely unlikely that the large bodies of the spermatozoa are so carried in; an improbability which is raised almost to a certainty by the fact that the spermatozoa are not seen attached to the egg with a centripetal direction of the axis of their bodies, but are constantly applied laterally to, or are entangled amongst the loose tissue of the surface, extended at length or partially folded on themselves.

6. AGENCY OF SPERMATOZOA AS AFFECTED BY CHEMICAL MEDIA.

The experiments with carmine having led to an unexpected result in the impediment which this medium offers to the impregnation of the ovum when immersed in it before contact with the spermatozoa, I was desirous of ascertaining what effect would be produced on the ovum by the destruction of the spermatozoa by chemical means, immediately after they had been applied to it. Mr. Gulliver* long ago showed that the spermatozoa of different animals are variously affected by different chemical tests; and Dr. Frerichs†, more recently, has found that a solution of caustic potass has the property of entirely dissolving and destroying them. This material, therefore, seemed to be peculiarly fitted for the object in view. But before any experiment, in

* Proceedings of the Zoological Society, part 10. p. 101. July 26, 1842.

† In Cyclopædia of Anatomy and Physiology, Article "Semen," p. 506, January 1849.

which this was employed, could be relied on, it was necessary to confirm the facts ascertained by chemical investigation, by observing the mode of action of solutions of caustic potass, and other chemical agents on the spermatozoa, by means of the microscope. As my observations on the effect of chemical agents on the spermatozoa have been confined for the present to those of the Frog, I shall state the results of these observations with the microscope before mentioning the experiments.

All the observations were made immediately after the spermatozoa employed had been obtained, by the course already mentioned, and not by vivisection from the vesiculæ seminales or the testes, sources which are objectionable from the facts shown in Dr. Frerichs' analyses, that a large quantity of albumen is always found in the immature cells in the testes, with which the spermatozoa, obtained from that source, are constantly mixed, while there is no trace of albumen in the mature spermatozoa.

1. *Solution of Caustic Potass.*—The solution employed was in the proportion of twenty grains of caustic potass (*Potassa fusa*) to one ounce of water. This was the solution employed on most occasions in the following experiments, and which quickly and entirely dissolves the spermatozoa. When a drop of semen, in which the spermatozoa are active and abundant, covered by a pellicle of talc on a plate of glass, is attentively examined, while a very small quantity of the potass solution is applied to the edge of the talc, the act of dissolution is easily witnessed. As the solution spreads beneath the talc the spermatozoa first brought into contact with it are instantly destroyed, while the motions of those at a distance become slower and slower, until, when the fluid has nearly approached, they entirely cease. The instant the fluid comes into contact with the spermatozoa, they roll up on a sudden into a spiral form, the change commencing at the apex of the caudal extremity, and each becomes a rounded mass, which quickly dissolves and disappears in the homogeneous fluid. The action of the potass in this destruction of the spermatozoa, as seen by the microscope, is very similar to, in appearance, and strongly reminds one of the action of fire on the barbs of a feather, which become frizzled in an instant, leaving only a scoria that soon disappears.

2. *Nitrate of Potass.*—This, as in the preceding case, was in solution in the proportion of twenty grains to an ounce of water. It destroys the spermatozoa much less quickly than the caustic potass. When applied, as above, to the edge of the talc, the spermatozoa first become on a sudden motionless, and are in general elongated, and afterwards are very slowly dissolved.

3. *Diluted Acetic Acid.*—When this is applied to the spermatozoa in the same way as the solution of potass, it quickly destroys all signs of vitality. The movements immediately become slower and very soon entirely cease, and the spermatozoa are extended at full length, and are but rarely folded on themselves, as they usually are in natural death. I could not satisfy myself that the acid has any other effect on them chemically than that of contracting and rendering them smaller. It did not appear to dissolve them. Mr. Gulliver* has mentioned that the spermatozoa of the

* *Loc. cit.*

snake (*Natrix torquata*) are not affected by acetic acid, but he makes no reference to its action on those of the Frog.

4. *Gum-Arabic.*—A thick solution of gum appears to act on the spermatozoa mechanically only, and almost immediately deprives them of motion by the obstruction it opposes to them. When a minute drop of spermatic fluid is placed in the midst of one of gum solution, and covered with talc, those spermatozoa which have become mixed with the gum cease to move instantly, and remain with the tail and body coiled in various directions; while others at the edges and in the midst of the fluid, where they are less mixed with gum, still move feebly for a few seconds, but become motionless as the gum collects around them.

These circumstances will better enable us to understand the following experiments, the object of which was to endeavour to learn how far the influence of the spermatozoa, and the *act* of impregnation of the ovum partake of a chemical or of a mechanical nature; and also will help to determine the length of period of contact requisite for impregnation.

The following experiments bear on these inquiries:—

Potass experiments.—Set P. March 25, 1850. Atmosphere 48° Fahr. Water 46° Fahr.

No. 1. P.M. $1^h\ 40^m$.—*Fifty-four ova* were passed from the Frog on a dry surface, and were instantly bathed with recently-obtained impregnating fluid mixed with water; and at the lapse of *fifteen seconds* were washed by means of a hair-pencil loaded with the solution of caustic potass before mentioned; after which the eggs were again washed freely with water.

No. 2. P.M. $1^h\ 45^m$.—*Thirty-nine ova* were treated in precisely the same way, except that the interval between the application of impregnating fluid and the solution of potass was only *five seconds*.

The ova were removed, after the first day, to a room in which the average temperature was about 60° Fahr., and at the end of the *eighth day twenty-one embryos*, advanced to near the end of the *fourth period* of development, had been produced in No. 1, and *two embryos*, at a similar stage, in No. 2. This, at first thought, appeared to be an extraordinary fact, seeing that the solution of potass so quickly decomposes the spermatozoa, and even renders the ovum sterile, as was afterwards found; but, on examination of the details, the experiments admit of explanation:—*first*, the seminal fluid was employed immediately it was obtained, and *before* the application of the potass, which was not used, in the first case, until after a lapse of *fifteen seconds*, and in the second case, of *five seconds*; next, that in both instances the solution of potass was, as quickly as possible after its application, diluted and removed by repeated washing of the ova with water. Nevertheless, these experiments prove that the ovum becomes impregnated very quickly after the application of spermatozoa, and, in these cases, even within the short interval of *fifteen seconds* in the one, and *five seconds* in the other, the difference in the number of embryos produced in the two apparently indicating the extent in each of the deleterious effect of the solution.

No. 3. P.M. 1^h 50^m.—*Forty-seven ova* were passed on a dry surface, and spermatic fluid was instantly applied to them, and within *ten seconds* afterwards the ova were washed with the solution of potass, which was allowed to remain, and water was then added. At the end of the *eighth day* not a single embryo had been produced. The difference between this experiment and the above was the non-removal of the potass, and the more free bathing of the ova.

No. 4. P.M. 1^h 53^m.—*Forty-five ova* were passed on a dry surface, and were *first* bathed with solution of potass, and then with seminal fluid in water, and afterwards they were removed with No. 1 and 2, to higher temperature.

At the expiration of the *eighth* day *three embryos* had been formed. This result at first appeared to be more difficult of explanation than the former. But, when the circumstances are considered, it seems to admit of quite as easy an interpretation. The bathing of the ova freely with seminal fluid mixed with water, *five seconds after* the application of the solution of potass, diluted this solution too much to allow of its effect on the whole of the spermatozoa applied to the ova, while this very dilution enabled the impregnating influence of these bodies to take effect in some of the ova. The fact, however, leads to an inference of some importance with reference to the action of the potass on the envelopes of the ovum, and seems to show that this action is less immediate on the envelopes than on the spermatozoa.

No. 5. *Fifty-nine ova* were bathed with seminal fluid and water, and *five seconds afterwards* with a solution of nitrate of potass (in the proportion of twenty grains of the salt to one ounce of water), and water was then added to them.

No. 6. *Seventy-two ova* were treated in precisely the same way.

Not one embryo was produced in either of these experiments.

No. 7. *Forty-four ova* were washed with diluted *acetic acid* immediately after they had been shed from the female, and *five seconds afterwards*, seminal fluid with water was added to them.

No. 8. *Seventy-six ova* were washed with diluted acid, and treated in every way as in No. 7.

Not a single embryo was produced in either of these trials.

The action of acetic acid is almost instantaneous on the envelope of the ovum, which it quickly contracts, and renders slightly opaque.

Besides those media which act *chemically* on the spermatozoa and the ova, I made trial, in this and the two following sets of experiments, with a solution of gum-arabic, the effect of which appears to be entirely *mechanical*; and as the results are curious and seemingly important with reference to the nature of the agency of the spermatozoa in impregnation, I defer the mentioning of them until I have to show the effect of media which operate mechanically on the ovum or the spermatozoon in impregnation.

The result of the preceding experiments was so remarkable, that it seemed necessary that they should be repeated with greater precision, with reference to exact periods

of time, than can always be done when alone and unassisted. It was evident that a proper understanding of the nature of the act of impregnation, if ever this becomes known, will be led to chiefly by attention to the *periods of time* in which it is effected. I obtained therefore the assistance of a friend, to note the spaces of time which elapsed in each stage of the following experiments, so that these might be performed with the quickest dispatch, and the attention of the experimenter be not withdrawn from each until it was completed.

Set Q. March 30, 1850. Atmosphere 49° FAHR.

The seminal fluid employed in this set of experiments was not obtained from the usual source. From some cause or other it could not be so procured. I therefore killed a male frog, by dividing the spinal cord in the *medulla oblongata*, and pressed out the fluid from the testes, which were gorged with spermatozoa, as found by examination with the microscope. From the presence of a great number of spermatozoal cells, and from the water with which I mixed the fluid becoming slightly turbid and albuminous, it was seen that it was not fully matured, a circumstance to be borne in mind with reference to the experiments, which were commenced some minutes after the fluid had been thus obtained. It was doubtful also whether the eggs were quite mature.

It is necessary further to mention, that in these experiments two solutions of potass, with different proportions of the salt, were employed; one having twenty grains in one ounce of water, and which, to avoid repetitions, I shall designate "*strong solution*;" and the other having only eight grains of the salt in one ounce of the fluid, and which I shall refer to as the "*weak solution*."

No. 1. P.M. 4^h 45^m.—*Forty-five ova*, passed on a dry surface, were bathed with seminal fluid and water, and *five seconds afterwards* with the *weak solution* of potass, and were then washed, and placed in clean water. The whole time occupied in the experiment did not exceed *thirty-five seconds*.

On the following morning, segmentation was found to have taken place in *twelve ova*. This as well as the following sets of ova were then removed to a higher temperature, in which they were allowed to remain; but *no embryos* were produced.

No. 2. P.M. 4^h 58^m.—*Fifty-three ova* were treated in exactly the same way, but with the *strong solution* of potass; the *interval* between the application of the impregnating fluid and the solution being only *two seconds*, and the whole time occupied *forty-five seconds*.

Segmentation took place in *three or four ova*, but not completely. Several ova also were altered in form; but *not a single embryo* was produced.

No. 3. P.M. 4^h 52^m.—*One hundred and twenty-two ova*, passed on a dry surface, were immediately well bathed with seminal fluid and water, and *two seconds afterwards* with *weak solution* of potass, which was *allowed to remain with the ova*, and water was then added. The whole time occupied was *forty-five seconds*.

Segmentation took place in a great number of these ova, certainly from *fifty to*

sixty, and there were nine also which became shrivelled and decayed. Notwithstanding the great proportion of ova segmented, *not one produced an embryo.*

No. 4. P.M. 5^h.—*Sixty-six ova*, passed on a dry surface, were bathed as in No. 2, with impregnating fluid, and *one second afterwards* were washed quickly with *strong solution* of potass, and water was then added; the period occupied being *sixty-two seconds.*

Only *two ova* became segmented, while, excepting only eight or nine ova, the whole of the remainder were shrivelled, irregular, or compressed in form, and distinctly spoiled, apparently by the action of the potass, thus showing that endosmose and exosmose through the envelopes had taken place.

No. 5. P.M. 4^h 55^m.—*Fifty-four ova* were passed, and washed with the *weak solution* of potass, and *afterwards*, at an interval of *two seconds*, with impregnating fluid and water, and water was then added and allowed to remain. The whole time occupied was *fifty seconds.*

One ovum only became segmented; but several others had slightly altered their form to the obtuse oval, as if about to become divided: *no embryo* was produced.

No. 6. P.M. 5^h 2^m.—*Seventy-nine ova* were washed with *strong solution* of potass, and one *second* afterwards with impregnating fluid, and water was then added.

Not one ovum became segmented, nor did even one yelk retain its proper shape. The whole were irregular and spoiled. *Five ova* had the envelope clouded and opaque, and the surface of others was translucent with refracted light, like crystallized carbonate of lime. In one egg only had there been any attempt at segmentation. This experiment, like No. 4, seemed to show that the act of expansion of the chorion is an act of endosmose.

No. 7. P.M. 5^h 15^m.—*Nitrate of Potass. Seventy-seven ova* were passed on a dry surface, and were well bathed with impregnating fluid in water, and *one second* afterwards with a *weak* solution of nitrate of potass, and water was then added to them; the whole time occupied being *thirty seconds.*

Segmentation took place in *forty-three* of these ova, and the whole retained their natural form and size. The effect of the nitrate of potass, as compared with the caustic solution, was thus very marked, as showing that the momentary application of the nitrate does not prevent or arrest impregnation in weak solution (eight grains to one ounce of water), even when applied *after* the impregnating influence. The experiment was also interesting in another respect. It proved that the ova were susceptible of being impregnated, and that the fluid from the testes was efficient to induce the first evidences of impregnation. But none of these ova, or of the ova in the preceding experiments of this set, produced embryos. Subsequent observations will show that this failure was not due to the nitrate of potass, but perhaps was attributable to the conjoint causes of low temperature at the time of impregnation, and of some imperfection both in the seminal fluid and the ova.

No. 8. P.M. 5^h 9^m.—*Seventy-six ova* were washed with diluted *acetic acid* as in *Set* P,

No. 7, and *one second* afterwards with impregnating fluid, and water was then added to them. The time occupied was *forty-five seconds*.

The result was more decided than in the experiment referred to. The envelopes of the ova immediately became clouded, and no segmentation took place in any of the yelks, some of which became shrivelled and changed in form.

The result of the preceding experiments being doubtful as to the cause of the non-production of embryos, especially with reference to the first three, and the seventh experiments, in which many ova became segmented, I obtained some additional pairs of frogs from their native haunts, and within twenty-four hours afterwards, before they had in any way become debilitated by confinement, repeated the experiments at a higher temperature.

Set R. April 3, 1850. Atmosphere 60° Fahr.

No. 1. P.M. $3^h\ 5^m$.—*Eighty-two ova*, passed on a dry surface, were touched for *an instant only* with a pencil dipped in impregnating fluid and water, and *one second afterwards* were washed with *strong* solution of potass, and then with water, and water was then added. The whole time occupied was only *fifteen seconds*.

No. 2. *Twenty-five ova* were treated in precisely the same way with the same solution (which also was employed in the following experiments); the interval being *two seconds*, and the whole time *twenty seconds*.

Segmentation took place, but *only very partially*, in about *twelve ova* of the first, but completely in *one only* of the second experiment. The whole of the remaining ova were shrivelled and decayed; their envelopes exhibiting the same clouded and refractive property noticed in the last set. At the end of five days *two embryos* had been produced in the first experiment, and *one* in the second. It was thus far confirmatory of the experiments with potass in *Set* P, that if this salt be applied to the envelope *several seconds after* the application of the impregnating fluid, and be again *quickly removed or diluted* with water, impregnation may already have taken place, and the action of the caustic will not in that case affect the production of the embryo; especially if the experiment be made when the temperature of the surrounding medium is becoming increased. But if the solution be applied *before* the application of the seminal fluid, then the spermatozoa will in most cases be decomposed, and no impregnation follow. In either case, however, the undiluted solution acts also on the ovum itself within a very short period, and destroys or renders it sterile. This was further proved in the succeeding experiments.

No. 3. P.M. $3^h\ 10^m$.—*Fifty-eight ova* were passed on *a moistened surface*, and were immediately afterwards washed with the solution, and at the expiration of *one second* were bathed with seminal fluid and water; the time occupied being only *fifteen seconds*, as in No. 1.

No. 4. *Sixty-nine ova* were treated in exactly the same way, the interval being *one second*; and the whole time occupied only *twelve*.

Partial segmentation had taken place in *one ovum* of No. 3; but the whole of the

remaining ova, both in No. 3 and 4, were destroyed. Many of the yelks had begun to change form within the first hour, and the envelopes exhibited the same refractive appearance as in the previous experiments.

Anticipating from the former experiments what probably might be the ultimate result in these, I now determined to put beyond the possibility of doubt, both the fitness of the seminal fluid employed to effect impregnation and the healthiness of the ova, and their susceptibility to become impregnated; and to show from these facts that a non-production of the embryo *in this set of experiments* must be due to the action of the potass solution, and not to any unfitness in the spermatozoa or the ova. Accordingly,—

No. 5. P.M. 3^h 17^m.—*Sixty-two ova*, from the same female employed in the preceding experiments, were bathed with a portion of the seminal fluid and water which had been employed in No. 1 and 2, and were then placed side by side with these, in a separate dish.

At the expiration of *four hours and thirteen minutes*, the temperature being 60° FAHR., from *thirty to forty* of these ova had become segmented. Some of the ova had been injured mechanically, but nearly the whole that had not been injured were impregnated. On the *seventh day* there were *twenty-three embryos*, *thirteen* of which had already left the egg-envelopes; others were somewhat less advanced, thus proving the fitness of the seminal fluid to impregnate, and the ova to produce. The number of embryos too was fully as great as could have been expected, seeing that many of the ova had been slightly injured, and that the seminal fluid had already been *one hour and twenty-six minutes* mixed with water.

The result of this experiment was borne out by the following.

No. 6. P.M. 3^h 31^m.—*Nitrate of Potass.* *Seventy-four ova* were well bathed with impregnating fluid and water on a previously dry surface, and *one second* afterwards with a *strong solution* of nitrate of potass (twenty grains to one ounce of water), and water was then added to them; the whole time of the experiment being *twenty seconds*.

No. 7. *Fifty-nine ova* were treated in exactly the same way, save that the interval between the application of the impregnating fluid and the solution of potass was *three seconds*, and the whole period *twenty-five seconds*.

Segmentation commenced in each of these sets in *four hours and fourteen minutes*, when from *twelve* to *fifteen* ova were undergoing this change in No. 6, and *thirteen* in No. 7. At a later hour there were many more in each experiment only very partially segmented, and which proved to be unproductive. At the end of the *seventh day* there were *twelve embryos* in No. 6 advanced to the same stage as in the *simply artificial impregnation* No. 5, and *ten embryos* in No. 7, but at a little less early stage of growth, a circumstance which I attributed at the time to imperfect aëration.

No. 8. P.M. 3^h 37^m.—*Seventy-nine ova* were bathed with the same solution of nitrate of potass as above, and *three seconds afterwards* with impregnating fluid in water; the whole time occupied being *twenty seconds*.

Segmentation took place at a little later period in this than in the preceding experiments. It commenced at *four hours and twenty minutes*, when *twenty-five ova* were undergoing the change. This was a full proportion of impregnation as compared with No. 5, seeing that the impregnating fluid had already been mixed with water one hour and forty-six minutes. *Twenty-five embryos* were the result of this experiment.

The results thus support the explanation already given, with reference to the effect produced on the envelopes of the ovum being less immediate than on the spermatozoa; since, in this case, twice as many ova became segmented, and ultimately produced embryos, as in those experiments in which *the solution* was applied *after* the seminal fluid, and while endosmosis of the egg was most rapid, and when the solution remained undiluted.

The general results of this set of experiments, compared with those of the last *Set*, Q, appear also to show that the non-production of embryos in the whole of that set,—after segmentation had taken place in several of the experiments, as in Nos. 1, 2, and especially No. 3, with solutions of the caustic potass;—and still further, No. 7 with the *nitrate*,—may fairly be attributed to some defect in the seminal fluid or in the ova; since, if such were not the cause, and the failure had been due either to the chemical effect of the media on the ova, or to the moderate temperature of the atmosphere (49° Fahr.) at the time of experiment,—segmentation of the yelk would hardly have taken place. This supposition appears to be the more likely, when we recollect that in the *Set* Q, and *in that set only*, the impregnating fluid was obtained from the testes, compressed and broken down in water,—that the eggs were of doubtful maturity,—and that this was *the only set of experiments in which no embryos were ultimately produced*; although, I may now mention, that greater care was taken to ensure a favourable result than in most of these investigations,—the ova being removed at the end of twenty hours to an average temperature of 60° Fahr.,—were retained in flat shallow dishes,—and had the water changed daily. Both sets, however, Q and R, seem to prove that the *act* of impregnation, as evidenced in the fact of the yelk becoming segmented, must take place, or be commenced very rapidly; and, apparently, *almost at the instant of contact of the spermatozoon with the coverings of the ovum*; as seems to be shown in the fact, that segmentation took place in many of the ova when the space of time between the application of the spermatozoon, and that of the solution,—which previous observation (p. 225) showed was sufficient to decompose it immediately,—was scarcely more than *one* or *two seconds*. Thus in Q 4, and R 1, it must have commenced in the interval of *one second*, even when the strong solution was used; and in Q 2 and R 2 with the same solution in *two seconds*. When the weaker solution was used, a greater number of ova became affected in similar spaces of time, as in Q 2 and 3. These experiments seem to show that the *act* of impregnation had already been *commenced* before the application of the solution; as, in the experiments which are the converse of those now mentioned, in regard to the time when the spermatozoa and the solution were applied, a different result ensued. Thus when the *solution* was applied to the ovum *first* as in Q 6 and R 3 and 4, and *one*

second afterwards the impregnating fluid with spermatozoa, no impregnation, or but a very partial one, was effected. The ova in these three experiments amounted to *two hundred and six*, and yet only *one ovum* became very partially affected. A like result ensued even when the weaker solution was employed at an interval of *two seconds*, as in Q 5, when out of *fifty-four ova* segmentation occurred but in *one*.

When the interval between the application of the impregnating fluid, in the first instance, and that of the solution subsequently, was extended to *five seconds*, then a greater proportion of ova became segmented, as in Q 1, with the weak solution, when out of *forty-five* ova *twelve* became changed.

These were the results when the experiments were made at different temperatures, as at 49° FAHR. with the *Set* Q, and 60° FAHR. with the *Set* R. They cannot, therefore, be attributable to inertness of the fecundating agent, or of the object to be fecundated, occasioned by an unfavourable temperature of the surrounding medium. The fact of the occurrence of segmentation in some ova, but not in the majority of the ova of different experiments, as in Q 1, 2, 3 and 4, seems further to show that the influence of the momentary application of the potash solution was produced chiefly, and in the first instance, on the spermatozoa, or impregnating bodies, and not so immediately on the ova; since if the ova had been first, or most affected, none of them, probably, would have become impregnated.

Further, I may perhaps be allowed to remark, that the arrest of impregnation was due mainly to the nature of the chemical agent employed; and the extent of interference with the fecundatory process was in proportion to the more or less immediate action of this agent on the spermatozoon. Thus we have seen that but few ova were impregnated when the solutions of caustic potass were employed; but when the nitrate of potass was used as in Q 7, *forty-three* out of *seventy-seven ova* were segmented; while in R 6, 7 and 8, in which the total number of ova was *two hundred and twelve*, there were *fifty-three* segmented, and these produced *forty-seven embryos*.

The object of these sets of experiments, therefore,—that of endeavouring to ascertain within what period of time after the contact of the spermatozoon with the ovum its fecundatory function is exerted,—appears to have been somewhat fulfilled;—in so far as that in these experiments on the *Amphibia* the *commencement of the act of impregnation appears to have been almost instantaneous*. Yet there seems reason to believe that momentary contact of the impregnating body, even in the ovum of these animals, is not in itself sufficient to complete the fecundation, although it may tend to induce that condition of the yelk, segmentation, which we now are assured is always indicatory of its having been influenced by the fecundatory agent. If momentary contact were sufficient for the completion of the function, then partial impregnation, which so frequently takes place when spermatozoa are few in number, or in contact only for very brief periods, could hardly happen; while every ovum in which the process of cleavage is begun ought to pass through all its changes to the production of the embryo, circumstances being favourable to its development. But this we have

seen in the foregoing experiments is not the case. On the contrary, *duration* of at least some *seconds* of contact, varying no doubt in different tribes of animals, and, apparently also, *quantity* of spermatozoa, seem to be essential to fruitful and healthy impregnation, as appears to be shown in the *filtration experiments*, *Set* L 3, as compared with L 1 (p. 207). Possibly momentary contact may suffice to occasion segmentation, but certainly with *duration* of contact the ovum is fecundated.

This leads us further to inquire whether any endosmosis of the material substance of the spermatozoon is imbibed by the ovum during any period of impregnation, before or during segmentation of the yelk?—and whether those media which do not act chemically on the spermatozoon or the ovum can arrest the agency of the former? Bischoff has already shown that spermatozoa are in contact with the ovum in some Mammalia, the Rabbit* and Dog†, from quickly after the entrance of the ovum into the Fallopian tube until segmentation is nearly completed, and the yelk has acquired a tuberculated or mulberry-like surface. In the ovum of the Frog I have shown that the spermatozoa are in like manner seen on the envelopes from immediately after immersion in impregnating fluid until segmentation has commenced. In the Newt we have seen that *when impregnation is effected artificially*, they may be recognized on the surface for a much longer period,—from the time of contact with fluid, until the surface of the yelk has reacquired its original smoothness, a period, in my observations, of from thirty-six to forty-eight hours. The persistence of these bodies to a period after the first evident changes in the yelk have commenced, seems to favour a supposition that their function is not completed in momentary contact. Although we are at present unable to trace their influence beyond what is now stated, I think it can be shown that their function can be arrested by media which affect them mechanically, when submitted to such media at the moment of contact with the ovum.

7. AGENCY OF THE SPERMATOZOA AS AFFECTED BY MECHANICAL MEDIA.

The object of the next experiments was to learn whether the interposition of a dense fluid medium, which does not act chemically on the spermatozoa, would be as effectual in preventing the influence of these bodies on the ovum as in the *carmine experiments*, the effect of which seemed to be mechanical.

As the experiments were made at different periods, it will be seen, that although on two of these occasions the temperature of the atmosphere differed, the general results were similar.

Gum and Starch Experiments.—Set S. March 25, 1850. Atmosphere 48°.

(*a.*) *Gum.* No. 1. P.M. $2^h\ 22^m$.—*Seventy-six ova* were passed on a *dry surface* and were immediately bathed with a thick solution of gum-arabic, and *fifteen seconds afterwards* with seminal fluid and water, and fresh water was then added to them. The whole time of the experiment was *sixty seconds*.

* Entwickelungsgeschichte des Kaninchen-eies. 4to. 1842, tab. 2, 3 and 4, fig. 17 to 28.

† Entwickelungsgeschichte des Hunde-eies. 4to. 1845, tab. 1 and 2, figs. 10 to 16.

No. 2. *Fifty-eight ova* were treated in exactly the same way, the interval being about *fifteen seconds*, and the whole time *sixty*.

The seminal fluid employed was obtained from two males, the fluid used to No. 2 being from a male which had paired four days before. Out of the whole number of eggs in the two sets, amounting to one hundred and thirty-four, not one produced an embryo.

No. 3. March 30, 1850. P.M. 5^h 5^m. Atmosphere 49° FAHR.

One hundred and eight ova were passed on a *moist* surface, and were immediately bathed with a thick solution of gum as above, and one *second afterwards* with seminal fluid in water; the whole time occupied being *sixty seconds*.

Segmentation took place in *two*, or at most only *three* of these ova, and even in them very imperfectly, and much slower than in the corresponding ova of the set to which they belonged, *Set* Q (p. 228–9), in which the fluid employed was obtained from the testes of the Frog, and regarded as immature.

No. 4. P.M. 5^h 18^m.—*Fifty-eight ova* passed on a *moistened* surface were immediately bathed with solution of gum, and one *second afterwards* with seminal fluid from the same male as No. 3. The whole time occupied was *forty-five seconds*.

The result of these two experiments, as compared with others of the set to which they belonged, *Set* Q, was exceedingly curious. In the experiments with the nitrate of potass as in Q 7, segmentation was carried to some extent, and the divisions of the yelk were multiplied; while only *four ova* out of the fifty-eight, in this with gum, gave any evidence of segmentation, and the process was not advanced further, either in this or in the preceding experiment, No. 3, than to the completion of the primary division of the yelk into two hemispheres. Thus not only was the process entirely prevented in the great majority of the ova, but it was also very much retarded in those in which it did take place, and this simply, as it appeared, by the mechanical hindrance of the gum. Could it be that the effect was produced on the endosmic action of the yelk? These trials certainly appeared to show that the obstruction was a mechanical one. I need scarcely remark, that *no embryo* was produced in either of these experiments.

No. 5. April 3, 1850. P.M. 3^h 25^m. Atmosphere 60° FAHR.

Sixty-one ova were passed on a *moistened* surface and were immediately bathed *with impregnating fluid*, and *two seconds afterwards* with a thick solution of gum-arabic, and water was then added; the whole time occupied being only *twenty seconds*.

This experiment, when compared either with the four preceding ones, made at a temperature of the atmosphere eleven degrees lower, or with that which follows, No. 6, seems to point to the exact nature of the operation of the gum. At *four hours* and *five minutes* from *fifteen* to *twenty* ova had become segmented, and others were in the act of becoming so. At *seven hours and a half* more than one-half of the whole number had changed, and were perfectly healthy. Thus, in this case, in which the gum was applied *after* the seminal fluid, impregnation occurred *earlier* than in corresponding experiments of the same set, R 6, 7 and 8, with nitrate of potass, when it happened in from *four hours*, and *fourteen* to *twenty minutes*. It was even as

rapid as in the artificial impregnation, R 5 (p. 231), in which it took place in *four hours and thirteen minutes*. On the eighth day *twelve embryos* had been produced.

These facts seemed to show, precisely as in experiments with solutions of potass, that impregnation is commenced very quickly; and further, that it was not arrested by the gum when applied only *two seconds* after the spermatozoa, but that the change proceeds almost as uninterruptedly as in a perfectly natural impregnation, since the number of embryos was almost as great as in No. 5 R, seeing that the fluid employed had been obtained and mixed with water one hour and thirty-four minutes.

No. 6. P.M. 3^h 22^m.—*Seventy ova*, passed on a moistened surface, were bathed with a thick solution of gum, and *two seconds afterwards* with some of the impregnating fluid employed in the last experiment, and water was then added; the whole time occupied, as above, being only *twenty seconds*.

This experiment was the converse of the preceding. At *four hours and twenty-eight minutes* only one egg out of the whole had become segmented; but others gave signs of being about to change, and some hours later a few had done so, but there were not at most more than *ten*. At the end of the *seventh* day *two embryos* had been produced.

Thus while a comparison of these two experiments seems to show that the gum acts simply as a mechanical obstruction to the process of fecundation, this experiment, No. 6, when compared with Nos. 1 to 4, made at eleven degrees lower temperature, shows also the influence of a higher degree of temperature in accelerating fecundation.

The two following experiments were made with a view to test the efficiency of the fluid and ova employed, now at one hour and fifty minutes after the fluid had been obtained: when examined at this time with the microscope, there were still an abundance of active spermatozoa.

No. 7. P.M. 3^h 41^m.—*Eighty-five ova* were accordingly placed in water with some of the impregnating fluid and allowed to remain to test its efficacy.

At *four hours and twenty-four minutes* nearly the whole of the ova had become segmented, and on the seventh day *forty-two embryos* had been produced.

No. 8. P.M. 5^h 50^m.—*One hundred and thirty-two ova* were now passed into the remainder of the impregnating fluid, which had at this time been *four hours* mixed with water.

When examined at the end of five hours and ten minutes, not a single specimen had become impregnated. This was proved by the result, that at the end of seven days *not a single embryo* had been formed. The fluid had thus lost its fecundating property at the end of four hours in a temperature of 60° FAHR.

No. 9. April 6, 1850. Atmosphere 60° FAHR.

P.M. 1^h 50^m.—One more experiment was now made with the gum solution, for the purpose of comparing it with the following experiments with starch.

One hundred and twenty-two ova were passed on a dry surface and covered with a thick solution of gum, and *three seconds afterwards* with impregnating fluid that had been mixed with water only *thirty minutes*. The time occupied was not noted, but fresh water was added to the ova at the end of fourteen minutes.

Segmentation took place only, in two or three ova, at *four hours and twenty-four minutes*, and at the end of ten days only *three embryos* had been produced.

(*b.*) *Starch.* No. 10. P.M. $1^h\ 40^m$.—*One hundred and fifty-eight ova* were passed into a solution of starch in water, and at the end of *ten seconds* one-half of the whole quantity of seminal fluid, obtained from a single frog, and previously mixed with water, was added to them.

After the ova had remained in the solution and been gently agitated during twenty minutes, they were carefully washed and removed to clear water.

At *four hours and twenty-six minutes* only a very few of these ova, not more than eight or ten, had become segmented, notwithstanding the large quantity of recent impregnating fluid that had been added to them. At the end of ten days only *five embryos* had been produced.

It was remarkable that very few of the ova in this experiment cohered together, as the frog's ova almost invariably do when placed in fluid. On the contrary, most of them remained separate and isolated, although their envelopes had imbibed water and expanded to their usual extent in a similar space of time.

No. 11. P.M. $1^h\ 47^m$.—*Seventy-one ova* were passed on a perfectly dry surface, and immediately afterwards were covered, by means of a hair-pencil, with a thick solution of starch, and at the expiration of *ten seconds* with impregnating fluid, and water was quickly added.

The water was changed at the end of fifteen minutes. At *four hours and twenty-five minutes*, only two or three ova had become segmented. At the end of ten days *three embryos* had been produced.

The concluding experiment with starch was the counterpart of No. 5, with *gum*.

No. 12. P.M. $1^h\ 44^m$.—*One hundred and nineteen ova* were passed into water, with which one-eighth part only of the seminal fluid, obtained from the Frog, had already been mixed. *Two seconds* afterwards a solution of starch was added to these ova, and at the end of sixteen minutes they were removed to clear water.

In *four hours and twenty-six minutes* segmentation had commenced in many of these ova. The exact number I omitted to ascertain. But the change had taken place in a much shorter space of time, and was more general, although scarcely one-fourth part of the quantity of seminal fluid that had been employed in No. 10 was used in this case. Nevertheless, in ten days *twelve embryos* had been formed.

This experiment, therefore, was quite confirmatory of the conclusions drawn from its counterpart, No. 5, with *gum*, and Nos. 10 and 11 as fully bore out those deduced from Nos. 1 to 5, with the same; while the entire set seem to be in full accordance with the already arrived at conclusion, that fecundation is commenced almost immediately the fecundating body is in contact with the ovum. Thus, then, with regard to the nature of impregnation, we seem to have obtained sufficient proof that the *act* is effected through the agency of the spermatozoon, and not through that of the *liquor seminis*, as was formerly supposed.

TABLE II.—Experiments with Media that act *chemically* or *me-*

No. of experiments.	Date and hour of experiment.	Temperature at the time of the experiment. Atmosphere.	Water.	Mean daily temperature after the experiment.	Segmentation commenced in hours.	No. of eggs employed.	No. of eggs segmented.	Embryos at end of third stage.	Embryos at in days and hours.	Nature of the impregnating fluid.	Time, procured and mixed with water.
1850.											
Set P. 1.	March 25. P.M. 1 40	48	46	61	.....	54	.....	20	4d 12h	Semen and water.	10m
2.	P.M. 1 45	48	46	61	.....	39	.....	2	4d 12h	Semen and water.	15m
3.	P.M. 1 50	48	46	61	.....	47	.....	Not one.	Not one.	Semen and water.	20m
4.	P.M. 1 53	48	46	61	.....	45	.....	3	5d	Semen and water.	23m
5.	P.M. 2 21	48	46	61	.....	59	.....	Not one.	.....	Semen and water.	51m
6.	P.M. 2 26	48	46	61	.....	72	.....	Not one.	.....	Semen and water.	56m
7.	P.M. 2 16	48	46	61	.....	44	.....	Not one.	.....	Semen and water.	46m
8.	P.M.	48	46	61	.....	76	.....	Not one.	.....	Semen and water.	10m
Set S. 1.	P.M. 2 22	48	46	61	.....	76	.....	Not one.	.....	Semen and water.	52m
2.	P.M.	48	46	61	.....	58	.....	Not one.	.....	Semen add water.	12m
Set Q. 1.	30. P.M. 4 45	49	48	61·5	.....	45	12	Not one.	.....	Semen from testes.	10m
2.	P.M. 4 58	49	48	61·5	.....	53	4	Not one.	.....	Semen from testes.	23m
3.	P.M. 4 52	49	48	61·5	.....	122	50 to 60	Not one.	.....	Semen from testes.	17m
4.	P.M. 5	49	48	61·5	.....	66	2	Not one.	.....	Semen from testes.	25m
5.	P.M. 4 55	49	48	61·5	.....	54	1	Not one.	.....	Semen from testes.	20m
6.	P.M. 5 2	49	48	61·5	.....	79	.....	Not one.	.....	Semen from testes.	27m
7.	P.M. 5 15	49	48	61·5	.....	77	43	Not one.	.....	Semen from testes.	40m
8.	P.M. 5 9	49	48	61·5	.....	76	.....	Not one.	.....	Semen from testes.	34m
Set S. 3.	P.M. 5 5	49	48	...	18 to 20h at temp. 49 to 48°	108	3	Not one.	.....	Semen from testes.	30m
4.	P.M. 5 18	49	48	...	18 to 20h	58	4	Not one.	.....	Semen from testes.	43m
Set R. 1.	April 3. P.M. 3 5	60	...	...	4h	82	12 partial	2	6 to 7d	Semen and water.	1h 12m
2.	.....	60	...	...	.....	25	1	1	6 to 7d	Semen and water.	.....
3.	P.M. 3 10	60	...	...	4½h	58	1 partially	Not one.	.....	Semen and water.	1h 17m
4.	.....	60	...	...	.....	69	.....	Not one.	.....	Semen and water.	1h
5.	P.M. 3 17	60	...	...	4h 13m	62	30 to 40	23	5d	Semen and water.	1h 24m
6.	P.M. 3 31	60	...	...	4h 14m	74	12 to 15	12	5d	Semen and water.	1h 38m
7.	.....	60	...	...	4h 14m	59	13	10	5d	Semen and water.	.....
8.	P.M. 3 37	60	...	...	4h 20m	79	25	25	5d	Semen and water.	1h 46m
Set S. 5.	P.M. 3 25	60	...	...	4h 5m	61	33	11	5d	Semen and water.	1h 34m
6.	P.M. 3 22	60	...	...	4h 30m	70	10	2	7d	Semen and water.	1h 31m
7.	P.M. 3 41	60	...	...	4h 24m	85	74	42	6d	Semen and water.	1h 50m
8.	P.M. 5 50	60	...	...	.....	132	Not one.	.....	.....	.....	4 *hours*
Set S. 9.	6. PM. 1 50	60	...	...	4h 24m	122	3	3	7d	Semen and water.	30m
10.	P.M. 1 40	60	...	...	4h 20m	158	8 or 10	5	7d	Semen and water.	20m
11.	P.M. 1 47	60	...	...	4h 25m	71	3	3	7d	Semen and water.	27m
12.	P.M. 1 44	60	...	...	4h 18m	119	.....	12	5½d	Semen and water.	24m
					Total number	2634	369	176	in Sets P, Q, R, & S.		

RECAPITULATION AND CONCLUSIONS.

It may now be well to recapitulate briefly some of the facts and views derived from the foregoing observations and experiments. *First*, then, the *germinal vesicle* disappears in the Amphibia before impregnation; and before, or at the time of the bursting of the ovisac, and extrusion of the egg from the ovary into the cavity of the

chanically on the Spermatozoon or the Ovum in Impregnation.

Material employed.			Period of experiment.			Remarks.
Operating mechanically.	Operating chemically.	Quantity per ounce of water.	Interval *before* fluid.	Interval *after* fluid.	Whole period.	
.....	*Solut. caust. pot.*	℈j to ʒj.	.....	15 sec.	1m	No. 1 to 8 of this set removed after fifty minutes to temperature 61° Fahr. These ova were passed on a dry surface, and fluid applied freely with a pencil, and afterwards the potass washed off freely with water.
.....	Solut. caust. pot.	℈j to ʒj.	.....	5 sec.	40 sec.	
.....	Solut. caust. pot.	℈j to ʒj.	.....	10 sec.	30 sec.	Potass allowed to remain.
.....	Solut. caust. pot.	℈j to ʒj.	5 sec.	.....	30 sec.	Ditto, well bathed with fluid *after* potass.
.....	*Solut. nitr. pot.*	℈j to ʒj.	.....	6 sec.	30 sec.	Well bathed with solut. nitr. potass and water then added, the solution allowed to remain.
.....	Solut. nitr. pot.	.....	.....	5 sec.	30 sec.	
.....	*Acetic acid.*	ʒj to ʒj.	5 sec.	.....	20 sec.	Impregnating fluid applied quickly and profusely, and water then added.
.....	Acetic acid.	ʒj to ʒj.	5 sec.	.....	20 sec.	
Solut. *gum-arab.*	.....	.....	15 sec.	.....	1m	Water was added quickly after the gum, but not sufficient to remove it; one or two ova segmented.
Solut. gum-arab.	.....	.....	15 sec.	.....	1m	
.....	*Solut. caust. pot.*	*gr. viij to* ʒj.	.....	5 sec.	35 sec.	No. 1 to 8 of this set also removed at end of nineteen hours to high temperature, 62° Fahr., No. 1 and 2 being thoroughly bathed with seminal fluid.
.....	Solut. caust. pot.	℈j *to* ʒj.	.....	2 sec.	45 sec.	
.....	Solut. caust. pot.	Weak.	.....	2 sec.	45 sec.	Water added and solut. of potass not washed off.
.....	Solut. caust. pot.	Strong.	.....	1 sec.	62 sec.	Nearly the whole at twenty hours spoiled.
.....	Solut. caust. pot.	Weak.	2 sec.	.....	50 sec.	
.....	Solut. caust. pot.	Strong.	1 sec.	.....	45 sec.	All spoiled in a few hours.
.....	*Solut. nitr. pot.*	gr. viij to ʒj.	.....	1 sec.	30 sec.	Ova passed on a moist surface and *well bathed* with fluid.
.....	*Acetic acid dilut.*	.....	.....	1 sec.	45 sec.	
Solut. *gum-arab.*	.....	.....	1 sec.	.....	1m	This was a thick solution of gum and applied with difficulty, but freely and quickly; the eggs were then well bathed with fluid and allowed to remain in a low, and slightly diminishing temperature.
Solut. gum-arab.	.....	.....	1 sec.	.....	45 sec.	
.....	*Solut. caust. pot.*	Strong.	.....	1 sec.	15 sec.	Ova touched lightly for an instant only with the fecundating fluid, and water afterwards added.
.....	Solut. caust. pot.	Strong.	.....	2 sec.	20 sec.	
.....	Solut. caust. pot.	Strong.	1 sec.	.....	15 sec.	Time of applying the potass was from two to three seconds; the eggs were spoiling within twenty minutes.
.....	Solut. caust. pot.	Strong.	1 sec.	.....	12 sec.	
.....	.....	.....	.....	.....	.....	Made with *fecundating fluid* without solution of potass to test the above.
.....	*Solut. nitr. pot.*	Strong.	.....	1 sec.	20 sec.	These ova were passed on a dry surface and were then thoroughly bathed with seminal fluid and water.
.....	Solut. nitr. pot.	Strong.	.....	3 sec.	25 sec.	
.....	Solut. nitr. pot.	Strong.	3 sec.	.....	20 sec.	The fluid was applied *after* the solution.
Solut. gum-arab.	.....	.....	.....	2 sec.	20 sec.	Impregnation must thus have occurred very quickly.
Solut. gum-arab.	.....	.....	2 sec.	.....	20 sec.	
.....	.....	.....	.....	.....	.....	Made to test the fecundatory fluid at *two hours* after mixture with water.
.....	.....	.....	.....	.....	.....	Not one egg segmented or one embryo found.
Solut. gum-arab.	.....	.....	3 sec.	.....	.....	Gum applied thickly and the ova then bathed with fecundating fluid.
Solut. of starch.	.....	.....	10 sec.	.....	.....	The ova *passed into* the starch, and a large quantity of fluid then added.
Solut. of starch.	.....	.....	10 sec.	.....	.....	Ova passed on a dry surface, starch applied with a pencil.
Solut. of starch.	.....	.....	.....	2 sec.	16m	Changed to fresh water after sixteen minutes.

abdomen. It does not return to the centre of the yelk, nor escape to the surface, but is lost much nearer to the latter than to the former position; and its disappearance is the result of the endogenous development of cells in its interior. The egg is cast loose into the abdomen, and then consists only of the yelk mass in its vitelline membrane, and it is transferred to the mouth of the oviduct by the joint action of

the abdominal muscles and the motions of the viscera, and not necessarily through the aid of the male during copulation. *Second*, changes are going on in the constituents of the egg, both before and after oviposition as well in the unimpregnated as in the impregnated condition; but they soon cease in the former, and do not proceed to the cleaving or segmentation of the yelk. *Third*, that the egg is not susceptible of impregnation until after it has acquired the envelopes which it gains in the oviduct. *Fourth*, that endosmosis of the entire egg takes place through these envelopes, and is most rapid during the few minutes the egg is most susceptible of impregnation. Further, that this endosmosis is augmented and hastened by an increase, and is lessened and retarded by a diminution of temperature; and that the susceptibility of the egg to become impregnated, and produce, is in exactly the same condition with regard to heat; whether the egg be exposed to, or whether it be excluded from light. *Fifth*, that only extremely minute granules of solid matter can by any possibility pass into the tissue of the envelopes during endosmosis; and that there is no evidence whatever of the existence of a fissure or orifice, in the envelopes of the egg of the Amphibia, at the time of, or before impregnation, capable of admitting the spermatozoon to the interior of the yelk-membrane or its contents. *Sixth*, that it is the spermatozoon alone which effects impregnation; and that this does not take place until the spermatozoon is brought into immediate contact with the external envelopes of the ovum. *Seventh*, that the *liquor seminis*, when entirely separated from spermatozoa, certainly does not effect impregnation. *Eighth*, that although direct contact of the spermatozoa with the ovum is indispensable to effect impregnation, I have never been able to detect any traces of these bodies in contact with the yelk-membrane, or even within the substance of the external envelope. *Ninth*, that impregnation is *commenced* the instant the spermatozoa are brought into contact with the egg, but a certain *duration of contact* is essential to its completion. *Tenth*, that impregnation is not effected when the whole or the majority of the spermatozoa in contact with the envelopes have previously become motionless and, apparently, have lost vitality, as they are found to have done after the lapse of a longer or shorter period. *Eleventh*, that although an exceedingly minute quantity of spermatozoa suffice to impregnate the ovum, the phenomenon of impregnation takes place more tardily, even with duration of contact when the number is extremely limited, than when it is in full abundance, without excess; while when the quantity is deficient, or the duration of contact too limited, then the phenomenon is incomplete, and partial impregnation only is effected. *Twelfth*, *partial impregnation* is shown in imperfect segmentation of the yelk; and is due chiefly to the spermatozoa being insufficient in quantity, or in duration of contact, or inefficient through diminished vitality; and it may also result from diminished susceptibility in the ovum. *Thirteenth*, partial impregnation of the ovum is of frequent occurrence, as I found in my first experiments with fluid that had passed through filtering-paper, but which still contained a very few spermatozoa, either motionless or exceedingly feeble; and further, partial impregnation is of

much the most frequent occurrence when the ova are placed in dense fluid before contact with the spermatozoa, as in the experiments with carmine. *Lastly*, when the ova are only partially impregnated they are usually, and perhaps always unproductive.

These facts lead us to inquire, whether impregnation takes place through any catalytic influence of the spermatozoa as suggested by Bischoff*, while in a state of activity, and at the instant they are brought into contact with the ovum, or whether impregnation results from a diffluence of the spermatozoa thus brought into contact with the surface, the substance into which they may be dissolved being carried by endosmosis with the water imbibed through the tissues; or whether it is the result of the conjoint influence of both these conditions;—the first action induced being instantaneous and catalytic, and possibly dependent on the persistence of organic vitality in the spermatozoa, while the completion of the impregnation may depend on the imbibition of some material influence or substance derived from the impregnating body;—a view which the gradual disappearance of the bodies of the spermatozoa from the surface of the ovum, both in the Frog and Newt, seems to favour; as we have already seen that endosmosis is an active and important function of the envelopes of the ovum at the very period when impregnation is effected.

All the experiments now detailed seem to show that in those vertebrata which expel their ova into water before impregnation, as in the tail-less *Amphibia*, and in which—from the nature of the medium into which the ova are passed—we may infer that the function takes place most quickly, impregnation is commenced at the very instant of contact of the spermatozoon with the ovum, and even may be completed within very short spaces of time—but *duration* of at least some seconds of actual contact,—even in these animals' ova, is essential to the perfection of the function;—but this period, we may fairly conclude, may differ in different classes of animals, and possibly may have some relation to the greater or less facility with which the spermatozoa are brought into contact with the ova.

When the experiments last detailed are compared,—the effects produced by the application of media which influence the spermatozoon and the ovum chemically,—with those of which the effect is merely mechanical, we seem to have made some advance towards a future knowledge of the nature of the impregnating power. Although we are as yet entirely without proof that any material influence or substance is actually transmitted from the spermatozoon on the surface of the ovum to the yelk in the interior, we have evidence that fluids are imbibed by the ovum by endosmosis through its tissues; and although not a trace of the spermatozoon is detected in the interior of the ovum, we have seen that it remains for a long time on the surface, and gradually disappears, apparently by diffluence; so that it may be fair to conclude, that the agency of this body is material in its operation. On the other hand, the effect which we find is produced on the yelk by the direct and even momentary contact of the

* Müller's Archives, 1847.

spermatozoon with the envelopes of the ovum, seems closely to resemble that of the so-called catalytic power of certain known bodies, in so far as that contact, during only very short spaces of time, with the surface of the ovum, appears to be sufficient to induce certain changes in the interior. These changes, too, as known of catalysis, are carried only to a certain extent when the exciting agents,—in this instance the spermatozoa,—are feeble in action or but very few in number; and then, as we have seen, the yelk may become only more or less partially segmented; or the changes in it, having proceeded to a certain extent, may then become arrested, apparently from deficiency of the originally exciting cause. Then, again, we find that although segmentation of the yelk may take place, embryos are not produced unless there has been some continuance or duration of contact of the impregnating with the impregnated body; and that the number produced seems to have reference to the duration and to the full sufficiency of the exciting cause. But neither what we at present know of the so-called catalytic power or of endosmosis, appears alone to be sufficient to account for the whole of the phenomena of impregnation. Simple contact of the spermatozoon does not appear to be sufficient to determine the transmission of more or less of the material structural characters of the male parent to the offspring; while diffluence and endosmosis of the substance of the spermatozoon can hardly be imagined to occur in a brief second or two of time sufficiently to effect the full impregnation of the yelk, and induce its invariable consequence, segmentation. Possibly, we may hereafter find that the first changes induced by contact of the impregnating body are completed by its diffluence, and by the material constituents into which it is dissolved, being transferred to the yelk by endosmosis.

Description of the Plate.

PLATE XIV.

Fig. 1. The female Frog, *Rana temporaria*, dissected to show the situation of the entrance to the oviducts (*a*) at each side of the heart (*b*). The liver (*c*) is drawn back and removed a little from its natural position to show the spaces (*d*) along which the ova pass from the cavity of the abdomen to the mouths of the oviducts (*g*), to be received into the dilated or uterine portion of the ducts (*h*). (*i.*) The stomach. (*k.*) Intestine. (*l.*) Colon and rectum. (*m.*) The bladder.

Fig. 2. A portion of the commencement of the oviduct magnified, partially concealed by the root of the lung.

a. The entrance to the duct between the heart and liver. (*e.*) The suspensory ligament of the liver. (*f.*) The base of the lung around which the oviduct (*g*) passes.

Fig. 3. The female Frog, exhibiting the viscera *in situ* before the ova have left the ovaries (*p*) and with the oviducts (*g*) enlarged with secretion, for the for-

mation of the envelopes of the ova as they pass through to the uterine or dilated portions of the ducts (*h*).

Fig. 4. The female Frog after oviposition, with the organs of digestion and the liver removed to show the condition of the ovaries (*p*) with their fatty appendages (*q*), the hyoid and thyroid muscles (*n*) (*o*) (*p*), the lungs (*f*) and the contracted state of the oviducts (*g*), and their uterine enlargement (*h*) with the rectum (*l*), and the bladder (*m*) then beginning again to be enlarged.

Fig. 5. Structure of the ovarian ovum.

a. The ovum while still attached to the inner surface of the ovary and projecting into the cavity, exhibiting the dark surface within the ovisac, which is traversed by minute vessels (*b*).

Fig. 6. Vertical section of the ovum, showing the situation of the germinal vesicle and the canal in the yelk, which corresponds to the centre of the dark surface of the yelk.

Fig. 7. The presumed mode of disappearance of the vesicle.

Fig. 8. Spermatozoa of the Frog. *a* and *b* escaping from the vesicle of development, *c*, as seen on the egg after contact.

Fig. 9. An ovum with spermatozoa half an hour after impregnation.

Fig. 10. A small portion of surface of the yelk at the commencement of segmentation, highly magnified. (*a*.) Yelk-cells at the same period. (*b*.) The smaller cells of the last, more highly magnified.

Figs. 11 and 12. Examples of partial impregnation at twenty-eight hours after contact with the spermatozoa.

X. *A Mathematical Theory of Magnetism.* By William Thomson, *Esq., M.A., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow. Communicated by Lieut.-Colonel* Sabine, *R.A., For. Sec. R.S.*

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Introduction.

1. The existence of magnetism is recognized by certain phenomena of force which are attributed to it as their cause. Other physical effects are found to be produced by the same agency; as in the operation of magnetism with reference to polarized light, recently discovered by Mr. Faraday; but we must still regard magnetic force as the characteristic of magnetism, and, however interesting such other phenomena may be in themselves, however essential a knowledge of them may be for enabling us to arrive at any satisfactory ideas regarding the physical nature of magnetism, and its connection with the general properties of matter, we must still consider the investigation of the laws, according to which the development and the action of magnetic force are regulated, to be the primary object of a Mathematical Theory in this branch of Natural Philosophy.

2. Magnetic bodies, when put near one another, in general exert very sensible mutual forces; but a body which is not magnetic, can experience no force in virtue of the magnetism of bodies in its neighbourhood. It may indeed be observed that a body, M, will exert a force upon another body A; and again, on a third body B; although when A and B are both removed to a considerable distance from M, no mutual action can be discovered between themselves: but in all such cases A and B are, when in the neighbourhood of M, temporarily magnetic; and when both are under the influence of M at the same time, they are found to act upon one another with a mutual force. All these phenomena are investigated in the mathematical theory of magnetism, which therefore comprehends two distinct kinds of magnetic action:—the mutual forces exercised between bodies possessing magnetism, and the magnetization induced in other bodies through the influence of magnets. The First Part of this paper is confined to the more *descriptive* and *positive* details of the subject, with reference to the former class of phenomena. After a sufficient foundation has been laid in it, by the mathematical exposition of the distribution of magnetism in bodies, and by the determination and expression of the general laws of magnetic force, a Second Part will be devoted to the theory of magnetization by influence, or magnetic induction.

FIRST PART.—ON MAGNETS, AND THE MUTUAL FORCES BETWEEN MAGNETS.

CHAPTER I. *Preliminary Definitions and Explanations.*

3. A magnet is a substance which intrinsically possesses magnetic properties.

A piece of loadstone, a piece of magnetized steel, a galvanic circuit, are examples of the varieties of natural and artificial magnets at present known; but a piece of soft iron, or a piece of bismuth temporarily magnetized by induction, cannot, in unqualified terms, be called a magnet.

A galvanic circuit is frequently, for the sake of distinction, called an "electro-magnet;" but, according to the preceding definition of a magnet, the simple term, without qualification, may be applied to such an arrangement. On the other hand, a piece of apparatus consisting of a galvanic coil, with a soft iron core, although often called simply "an electro-magnet," is in reality a complex arrangement involving an electro-magnet (which is intrinsically magnetic as long as the electric current is sustained) and a body transiently magnetized by induction.

4. In the following analysis of magnets, the magnetism of every magnetic substance considered, will be regarded as absolutely permanent under all circumstances. This condition is not rigorously fulfilled either for magnetized steel or for loadstone, as the magnetism of any such substance is always liable to modification by induction, and may therefore be affected either by bringing another magnet into its neighbourhood, or by breaking the mass itself and separating the fragments. When, however, we consider the magnetism of any fragment taken from a steel or loadstone magnet, the hypothesis will be that it retains without any alteration the magnetic state which it actually had in its position in the body. The general theory of the distribution of magnetism founded upon conceptions of this kind, will be independent of the truth or falseness of any such hypothesis which may be made for the sake of convenience in studying the subject; but of course any actual experiments in illustration of the analysis or synthesis of a magnet would be affected by a want of *rigidity* in the magnetism of the matter operated on. For such illustrations, electro-magnets are extremely appropriate, as in them, except during the motion by which any alteration in their form or arrangement is effected, no appreciable inductive action can exist.

5. In selecting from the known phenomena of magnetism those elementary facts which are to serve for the foundation of the theory, all complex actions, depending on the irregularities of the bodies made use of, should be excluded. Thus if we were to attempt an experimental investigation of the action between two amorphous fragments of loadstone, or between two pieces of steel magnetized by ordinary processes, we should probably fail to recognize the simple laws on which the actions, resulting from such complicated circumstances, depend; and we must look for a simpler case of magnetic action before we can make an analysis which may lead to the establishment of the fundamental principles of the theory. Much complication will be avoided if we take a case in which the irregularities of one at least of the bodies do not affect the phenomena to be considered. Now the earth, as was first shown by GILBERT, is a magnet; and its dimensions are so great that there is no sensible

variation in its action on different parts of any ordinary magnet upon which we can experiment, and consequently, in the circumstances, no complicacy depending on the actual distribution of terrestrial magnetism. We may therefore, with advantage, commence by examining the action which the earth produces upon a magnet of any kind at its surface.

6. At a very early period in the history of magnetic discovery, the remarkable property of "pointing north and south" was observed to be possessed by fragments of loadstone and magnetized steel needles. To form a clear conception of this phenomenon, we must consider the total action produced by the earth upon a magnet of any kind, and endeavour to distinguish between the effects of gravitation which the earth exerts upon the body in virtue of its weight, and those which result from the magnetic agency.

7. In the first place, it is to be remarked that the magnetic agency of the earth gives rise to no resultant force of sensible magnitude, upon any magnet with reference to which we can perform experiments, as is proved by the following observed facts.

(1.) A magnet placed in any manner, and allowed to move with perfect freedom in any horizontal direction (by being floated, for example, on the surface of a liquid), experiences no action which tends to set its centre of gravity in motion, and there is therefore no horizontal force upon the body.

(2.) The magnetism of a body may be altered in any way, without affecting its weight as indicated by a balance. Hence there can be no vertical force upon it depending on its magnetism.

8. It follows that any magnetic action which the earth can exert upon a magnet must be a couple. To ascertain the manner in which this action takes place, let us conceive a magnet to be supported by its centre of gravity* and left perfectly free to turn round this point, so that without any constraint being exerted which could balance the magnetic action, the body may be in circumstances the same as if it were without weight. The magnetic action of the earth upon the magnet gives rise to the following phenomena:—

(1.) The body does not remain in equilibrium in every position in which it may be brought to rest, as it would do did it experience no action but that of gravitation.

(2.) If the body be placed in a position of equilibrium, there is a certain axis (which, for the present, we may conceive to be found by trial), such, that if the body be turned round it, through any angle, and be brought to rest, it will remain in equilibrium.

(3.) If the body be turned through 180°, about an axis perpendicular to this, it will again be in a position of equilibrium.

* The ordinary process for finding experimentally the centre of gravity of a body, fails when there is any magnetic action to interfere with the effects of gravitation. It is, however, for our present purpose, sufficient to know that the centre of gravity exists; that is, that there is a point such that the vertical line of the resultant action of gravity passes through it, in whatever position the body be held. If it were of any consequence, a process, somewhat complicated by the magnetic action, for actually determining, by experiment, the centre of gravity of a magnet might be indicated, and thus the experimental treatment of the subject in the text would be completed.

(4.) Any motion of the body whatever, which is not of either of the kinds just described, nor compounded of the two, will bring it into a position in which it will not be in equilibrium.

(5.) The directing couple experienced by the body in any position depends solely on the angle of inclination of the axis described in (1.) to the line along which it lies when the body is in equilibrium; being independent of the position of the plane of this angle, and of the position of the body with reference to that axis.

9. From these observations we draw the conclusion that a magnet always experiences a directing couple from the earth, unless a certain axis in the body is placed in a determinate position. This line in the body is called its magnetic axis*.

10. The direction towards which the magnetic axis of the body tends in virtue of the earth's action, is called "the line of dip," or "the direction of the total terrestrial magnetic force," at the locality of the observation.

11. No further explanation regarding phenomena which depend on terrestrial magnetism is required in the present chapter; but, as the facts have been stated in part, it may be right to complete the statement, as far as regards the action experienced by a magnet of any kind when held in different positions in a given locality, by mentioning the following conclusions, deduced in a very obvious manner from the general laws of magnetic action stated below, and verified fully by experiment.

If a magnet be held with its magnetic axis inclined at any angle to the line of dip, it will experience a couple, the moment of which is proportional to the sine of the angle of inclination, acting in a plane containing the magnetic axis and the line of dip. The position of equilibrium towards which this couple tends to bring the magnetic axis is stable, and if the direction of the magnetic axis be reversed, the body may be left balanced, but it will be in unstable equilibrium.

12. The directive tendency observed in magnetic bodies, being found to depend on their geographical position, and to be related in some degree to the terrestrial poles, received the name of *polarity*; probably on account of a false hypothesis of forces exercised by the pole-star† or by the earth's poles, upon certain points of the loadstone or needle, thence called the "poles of the magnet." The terms "polarity" and "poles" are still retained, but the use of them which has very generally been made, is nearly as vague as the ideas from which they had their origin. Thus when the magnet is an elongated mass, its ends are called poles if its magnetic axis be in the direction of its length; no definite points, such as those in which the surface of the body is cut by the magnetic axis, being precisely indicated by the term as it is

* Any line in the body parallel to this might, with as good reason, be called a magnetic axis, but when we conceive the magnet to be supported by its centre of gravity, the magnetic axis is naturally taken as a line through this point.

† In the poem of Guiot de Provence (quoted in Whewell's History of the Inductive Sciences, vol. ii. p. 46), a needle is described as being magnetized and placed in or on a straw (floating on water it is to be presumed)—

"Puis se torne la pointe toute
Contre l'estoile sans doute."

generally used. If, however, the body be symmetrical about its magnetic axis, and symmetrically magnetized, whether elongated in that direction or not, the poles might be definitely the *ends of the magnetic axis* (or the points in which the surface is cut by it), unless the magnet be annular and not cut by its magnetic axis (a ring electro-magnet, for instance), in which case the ordinary conception of *poles* fails. Notwithstanding this vagueness, however, the terms poles and polarity are extremely convenient, and, with the following explanations, they will frequently be made use of in this paper.

13. Let O be any point in a magnet, and let N O S be a straight line parallel to the line defined above as the magnetic axis through the centre of gravity. If the point O, however it has been chosen, be called the centre of the magnet, the line N S, terminated either at the surface, on each side, or in any arbitrary manner, is called the magnetic axis, and the ends, N, S, of the magnetic axis are called the poles of the magnet*.

14. That pole (marked N) which points, on the whole, from the north, and in northern latitudes upwards, is called the north pole, and the other (S), which points from the south, is called the south pole.

15. The *sides* of the body towards its north pole and south pole, are said to possess "northern polarity" and "southern polarity" respectively, an expression obviously founded on the idea that the surface of a magnet may in general be contemplated as a locus of poles.

16. If a magnetic body be broken up into any number of fragments, each morsel is found to be a complete magnet, presenting in itself all the phenomena of poles and polarity. This property is generally contemplated when, in modern writings on physical subjects, polarity is mentioned as a property belonging to a solid body; and a corresponding idea is involved in the term when it is applied with reference to the electric state which Mr. FARADAY discovered to be induced in non-conductors of electricity ("dielectric"), when subjected to the influence of electrified bodies†. However different are the physical circumstances of magnetic and electric polarity, it appears that the positive laws of the phenomena are the same‡, and therefore the mathematical theories are identical. Either subject might be taken as an example of a very important branch of physical mathematics, which might be called "A Mathematical Theory of Polar Forces."

17. Although we have seen that any magnet, in general, experiences from the earth an action subject to certain very simple laws, yet the actual distribution of the magnetism which it possesses may be extremely irregular. We may certainly conceive

* A definition of poles at variance with this is adopted in some special cases, especially in that of the earth considered as a great magnet, but the manner in which the term will be used in this paper will be such as to produce no confusion on this account.

† FARADAY's Experimental Researches in Electricity, Eleventh Series.

‡ See a paper "On the Elementary Laws of Statical Electricity," published in the Cambridge and Dublin Mathematical Journal (vol. i.) in December 1845.

that if the magnetized substance be a regular crystal of magnetic iron ore, the magnetism is distributed through it according to some simple law; but by taking an amorphous and heterogeneous fragment of ore presenting magnetic properties, by magnetizing in any way an irregular mass of steel, by connecting any number of morsels of magnetic matter so as to make up a complex magnet, or by bending a galvanic wire into any form, we may obtain magnets in which the magnetic property is distributed in any arbitrary manner, however irregular. Excluding for the present the last-mentioned case, let us endeavour to form a conception of the distribution of magnetism in actually magnetized matter, such as steel or loadstone, and to lay down the principles according to which it may in any instance be mathematically expressed.

18. In general we may consider a magnet as composed of matter which is magnetized throughout, since, in general, it is found that any fragment cut out of a magnetic mass is itself a magnet possessing properties entirely similar to those which have been described as possessed by any magnet whatever. It may be however that a small portion cut out of a certain position in a magnet, may present no magnetic phenomena; and if we cut equal and similar portions from different positions, we may find them to possess magnetic properties differing to any extent both in intensity, and in the directions of their magnetic axes.

19. If we find that equal and similar portions, cut in parallel directions, from any different positions in a given magnetic mass, possess equal and similar magnetic properties, the mass is said to be uniformly magnetized.

20. In general, however, the intensity of magnetization must be supposed to vary from one part to another, and the magnetic axes of the different parts to be not parallel to one another. Hence, to lay down determinately a specification of the distribution of magnetism through a magnet of any kind, we must be able to express the *intensity* and the *direction* of magnetization at each point. Before attempting to define a standard for the numerical expression of intensity in magnetization, it will be convenient to examine the elementary laws upon which the phenomena of magnetic force depend, since it is by these effects that the nature and energy of the *magnetism* to which they are due must be estimated.

Chapter II. *On the Laws of Magnetic Force, and on the Distribution of Magnetism in Magnetized Matter.*

21. The object of the elementary magnetic researches of Coulomb was the determination of the mutual action between two infinitely thin, uniformly and longitudinally magnetized bars. The magnets which he used were in strictness neither uniformly nor longitudinally magnetized, such a state being unattainable by any actual process of magnetization; but, as the bars were very thin cylindrical steel wires, and were symmetrically magnetized, the resultant actions were sensibly the same as if they were in reallty infinitely thin, and longitudinally magnetized; and from experi-

ments which he made, it appears that the intensity of the magnetization must have been very nearly constant from the middle of each of the bars, to within a short distance from either end, where a gradual decrease of intensity is sensible*.

22. These circumstances having been attended to, COULOMB was able to deduce from his experiments the true laws of the phenomena, and arrived at the following conclusions:—

(1.) If two thin uniformly and longitudinally magnetized bars be held near one another, an action is exerted between them which consists of four distinct forces, along the four lines joining their extremities.

(2.) The forces between like ends of the two bars are repulsive†.

(3.) The forces between unlike ends are attractive.

(4.) If the bars be held so that the four distances between their extremities, two and two, are equal, the four forces between them will be equal.

(5.) If the relative positions of the bars be altered, each force will vary inversely as the square of the mutual distance of the poles between which it acts.

23. To establish a standard for estimating the *strength* of a magnet, let us conceive two infinitely thin bars to be placed so that either end of one may be a unit of distance from an end of the other. Then, if the bars be equally magnetized, each uniformly and longitudinally, to such a degree that the force between those ends shall be unity, the strength of each bar-magnet is unity‡.

24. If any number, m, of such unit bars, of equal length, be put with like ends together, so as to constitute a single complex bar, the strength of the magnet so formed is denoted by m.

If there be any number of thin bar-magnets of equal length, and each of them of such a strength that q of them, with like ends together, would constitute a unit-bar; and if p of those bars be put with like ends together, the strength of the complex magnet so formed will be $\frac{p}{q}$.

25. If a single infinitely thin bar be magnetized to such a degree that in the same positions it would produce the same effects as a complex bar of any strength m (an integer or fraction), the strength of this magnet is denoted by m.

26. If two complex bar-magnets, of the kind described above, be put near one an-

* See note on § 38, below.

† Hence we see the propriety of the terms *north* and *south* applied to the opposite polarities of a magnet, as explained above. Thus we designate the polarity, or the imaginary magnetic matter, of the northern and southern magnetic hemispheres of the earth, as northern and southern respectively; and since the poles of ordinary magnets which are repelled by the earth's northern or southern polarity must be *similar*, these also are called northern or southern, as the case may be.

‡ The Royal Society in its Instructions for making observations on Terrestrial Magnetism adopts one foot as the unit of length; and, that force which, if acting on a grain of matter, would in one second of time generate one foot per second of velocity, as the unit of force; which is consequently very nearly $\frac{1}{32\cdot 2}$ of the weight, in any part of Great Britain or Ireland, of one grain.

other, each bar of one will act on each bar of the other with the same forces as if all the other bars were removed. Hence, if the distance between the two poles be unity, and if the strengths of the bars be respectively m and m', (whether these numbers be integral or fractional,) the force between those poles will be mm'. If, now, the relative position of the magnets be altered, so that the distance between two poles may be f, the force between them will, according to COULOMB's law, be

$$\frac{m\,m'}{f^2}.$$

According to the definition given above of the strength of a simple bar-magnet, it follows that the same expression gives the force between two poles of any thin, uniformly and longitudinally magnetized bars, of strengths m and m'.

27. The *magnetic moment* of an infinitely thin, uniformly and longitudinally magnetized bar, is the product of its length into its strength.

28. If any number of equally strong, uniformly and longitudinally magnetized rectangular bars of equal infinitely small sections, be put together, with like ends towards the same parts, a complex uniformly magnetized solid of any form may be produced. The *magnetic moment* of such a magnet is equal to the sum of the magnetic moments of the bars of which it is composed.

29. The magnetic moment of any continuous solid, uniformly magnetized in parallel lines, is equal to the sum of the magnetic moments of all the thin, uniformly and longitudinally magnetized bars into which it may be divided.

It follows that the magnetic moment of any part of a uniformly magnetized mass is proportional to its volume.

30. The *intensity of magnetization* of a uniformly magnetized solid is the magnetic moment of a unit of its volume.

It follows that the magnetic moment of a uniformly magnetized solid, of any form and dimensions, is equal to the product of its volume into the intensity of its magnetization.

31. If a body be magnetized in any arbitrary, regular or irregular manner, a portion may be taken in any position, so small in all its dimensions that the distribution of magnetism through it will be sensibly uniform. The quotient obtained by dividing the magnetic moment of such a portion, in any position P, by its volume, is the *intensity of magnetization* of the substance at the point P; and a line through P parallel to its lines of magnetization, is the *direction of magnetization*, at P.

CHAPTER III. *On the Imaginary Magnetic Matter by means of which the Polarity of a Magnetized Body may be represented.*

32. It will very often be convenient to refer the phenomena of magnetic force to attractions or repulsions mutually exerted between portions of an imaginary magnetic matter, which, as we shall see, may be conceived to represent the polarity of a magnet of any kind. This imaginary substance possesses none of the primary qualities

of ordinary matter, and it would be wrong to call it either a solid, or the "magnetic fluid," or "fluids"; but, without making any hypothesis whatever, we may call it "magnetic matter," on the understanding that it possesses only the property of attracting or repelling magnets, or other portions of "matter" of its own kind, according to certain determinate laws, which may be stated as follows:—

(1.) There are two kinds of imaginary magnetic matter, northern and southern, to represent respectively the northern and southern magnetic polarities of the earth, or the similar polarities of any magnet whatever.

(2.) Like portions of magnetic matter repel and unlike portions attract, mutually.

(3.) Any two small portions of magnetic matter exert a mutual force which varies inversely as the square of the distance between them.

(4.) Two units of magnetic matter, at a unit of distance from one another, exert a unit of force, mutually.

33. If quantities of magnetic matter be measured numerically in such units, and if the positive or negative sign be prefixed to denote the *species* of matter, whether *northern* (which, by convention, we may call *positive*) or *southern*, all the preceding laws are expressed in the following proposition:—

If quantities, m *and* m′, *of magnetic matter be concentrated respectively at points at a distance,* f, *from one another, they will repel with a force algebraically equal to*

$$\frac{m\,m'}{f^2}.$$

34. It appears from the explanations given above, that the circumstances of a uniformly magnetized needle may be represented if we imagine equal quantities of northern and southern magnetic matter to be concentrated at its two poles, the numerical measure of these equal quantities being the same as that of the "strength" of the magnet.

The mutual action between two needles would thus be reduced to forces of attraction and repulsion between the portions of magnetic matter by which their poles are represented.

35. Any magnetic mass whatever may, as we have seen, be regarded as composed of infinitely small bar-magnets put together in such a way as to produce the distribution of magnetism which it actually possesses; and hence, by replacing the poles of these magnets by imaginary magnetic matter, we obtain a distribution of equal quantities of northern and southern magnetic matter through the magnetized substance, by which its actual magnetic condition may be represented. The distribution of this matter becomes very much simplified from the circumstance that we have in general unlike poles of the elementary magnets in contact, by which the opposite kinds of magnetic matter are partially (or in a class of cases *wholly**) destroyed through the interior of the body. The determination of the resulting distribution of

* In all cases when the distribution is "solenoidal." See below, Chap. V. § 68. Communicated to the Royal Society, June 20, 1850.

magnetic matter, which represents in the simplest possible manner the polarity of any given magnet, is of much interest, and even importance, in the theory of magnetism, and we may therefore make this an object of investigation, before going farther.

36. Let it be required to find the distribution of imaginary magnetic matter to represent the polarity of any number of uniformly magnetized needles, S_1N_1, S_2N_2, ... S_nN_n of strengths μ_1, μ_2, ... μ_n respectively, when they are placed together, end to end (not necessarily in the same straight line).

If A denote the position occupied by S_1 when the bars are in their places; if N_1 and S_2 are placed in contact at K_1; N_2 and S_3 at K_2; and so on until we have the last magnet, with its end S_n, in contact with N_{n-1}, at K_{n-1}, and its other end, N_n, free, at a point B; we shall have to imagine

μ_1 units of southern magnetic matter to be placed at A;
μ_1 units of northern, and μ_2 units of southern matter at K_1;
μ_2 units of northern, and μ_3 of southern matter at K_2;
. . . . . .
μ_{n-1} units of northern, and μ_n of southern matter at K_{n-1};
and lastly, μ_n units of northern matter at B.

Hence the final distribution of magnetic matter is as follows:—

$-\mu_1$	at A
$\mu_1-\mu_2$	K_1
$\mu_2-\mu_3$	K_2
. . . . .	
. . . . .	
$\mu_{n-1}-\mu_n$	K_{n-}
and μ_n	B.

37. The complex magnet $AK_1K_2 \ldots K_{n-1}B$ consists of a number of parts, each of which is uniformly and longitudinally magnetized, and it will act in the same way as a simple bar of the same length, similarly magnetized; and hence the magnetic matter which represents a bar-magnet AB of this kind is concentrated in a series of points, at the ends of the whole bar, and at all the places where there is a variation in the strength* of its magnetization.

38. If the length of each part through which the strength of the magnetism is constant, be diminished without limit, and if the entire number of the parts be increased indefinitely, a straight or curved infinitely thin bar may be conceived to be produced, which shall possess a distribution of longitudinal magnetism varying continuously from one end to the other according to any arbitrary law. If the strength of the magnetism at any point P of this bar be denoted by μ, and if $[\mu]$ and (μ) denote

* This expression is equivalent to *the product of the intensity of magnetization into the section of the bar*; and by retaining it we are enabled to include cases in which the bar is not of uniform section.

the values of μ at the points A and B, the investigation of § 36, with the elementary principles and notation of the differential calculus, leads at once to the determination of the ultimate distribution of magnetic matter by which such a bar-magnet may be represented. Thus if AP be denoted by s; μ will be a function of s, which may be supposed to be known, and its differential coefficient will express the continuous distribution of magnetic matter which replaces the group of material points at K_1, K_2, &c.; so that the entire distribution of polarity in the bar and at its ends will be as follows:—in any infinitely small length, σ, of the bar, a quantity of matter equal to

$$-\frac{d\mu}{ds}\cdot\sigma,$$

and, besides, terminal accumulations, of quantities

$$-[\mu] \text{ at A}$$

and

$$(\mu) \text{ at B.}$$

It follows that if through any part of the length of a bar, the strength of the magnetism is constant, there will be no magnetic matter to be distributed through this portion of the magnet; but if the strength of the magnetism varies, then, according as it diminishes or increases from the north to the south pole of any small portion, there will be a distribution of northern or southern magnetic matter to represent the polarity which results from this variation.

Corresponding inferences may be made conversely, with reference to the distribution of magnetism, when the distribution of the imaginary magnetic matter is known. Thus Coulomb found that his long thin cylindrical bar-magnets acted upon one another as if each had a symmetrical distribution of the two kinds of magnetic matter, northern within a limited space from one end, and southern within a limited space from the other, the intermediate space (constituting generally the greater part of the bar) being unoccupied; from which we infer that no variation in the magnetism was sensible through the middle part of the bar, but that, through a limited space on each side, the intensity of the magnetization must have decreased gradually towards the ends*.

39. The distribution of magnetic matter which represents the polarity of a uniformly magnetized body of any form, may be immediately determined if we imagine

* This circumstance was alluded to above, in § 21. Interesting views on the subject of the distribution of magnetism in bar-magnets are obtained by taking arbitrary examples to illustrate the investigation of the text. Thus we may either consider a uniform bar variably magnetized, or a thin bar of varying thickness, cut from a uniformly magnetized substance; and according to the arbitrary data assumed, various remarkable results may be obtained. We shall see afterwards that any such data, however arbitrary, may be actually produced in electro-magnets, and we have therefore the means of illustrating the subject experimentally, in as complete a manner as can be conceived, although from the practical *non-rigidity* of the magnetism of magnetized substances, ordinary steel or loadstone magnets would not afford such satisfactory illustrations of *arbitrary* cases as might be desired. The distribution of longitudinal magnetism in steel needles actually magnetized in different ways, and especially "magnetized to saturation," has been the object of interesting experimental and theoretical investigations by Coulomb, Biot, Green and Riess.

it divided into infinitely thin bars, in the directions of its lines of magnetization; for each of these bars will be uniformly and longitudinally magnetized, and therefore there will be no distribution of matter except at their ends. Now the bars are all terminated on each side by the surface of the body, and consequently the whole magnetic effect is represented by a certain superficial distribution of northern and southern magnetic matter. It only remains to determine the actual form of this distribution; but, for the sake of simplicity in expression, it will be convenient to state previously the following definition, borrowed from COULOMB's writings on electricity.

40. If any kind of matter be distributed over a surface, the *superficial density* at any point is the quotient obtained by dividing the quantity of matter on an infinitely small element of the surface in the neighbourhood of that point, by the area of the element.

41. To determine the superficial density at any point in the case at present under consideration, let ω be the area of the perpendicular section of an infinitely thin uniform bar, of the solid, with one end at that point. Then, if i be the intensity of magnetization of the solid, $i\omega$ will be, as may be readily shown, the "strength" of the bar-magnet. Hence at the two ends of the bar we must suppose to be placed quantities of northern and southern imaginary magnetic matter each equal to $i\omega$. In the distribution over the surface of the given magnet, these quantities of matter must be imagined to be spread over the oblique ends of the bar. Now if θ denote the inclination of the bar to a normal to the surface through one end, the area of that end will be $\frac{\omega}{\cos\theta}$, and therefore in that part of the surface we have a quantity of matter equal to $i\omega$ spread over an area $\frac{\omega}{\cos\theta}$. Hence the superficial density is

$$i\cos\theta.$$

This expression gives the superficial density at any point, P, of the surface, and its algebraic sign indicates the kind of matter, provided the angle denoted by θ be taken between the external part of the normal, and a line drawn from P in the same direction as that of the motion of a point carried from the south pole, to the north pole, of a portion close to P, of the infinitely thin bar-magnet which we have been considering.

42. Let it be required, in the last place, to determine the entire distribution of magnetic matter necessary to represent the polarity of any given magnet.

We may conceive the whole magnetized mass to be divided into infinitely small parallelepipeds by planes parallel to three planes of rectangular coordinates. Let α, β, γ denote the three edges of one of these parallelepipeds having its centre at a point P (x, y, z). Let i denote the given intensity, and l, m, n the given direction cosines of the magnetization at P. It will follow from the preceding investigation that the polarity of this infinitely small, uniformly magnetized parallelepiped, may be represented by imaginary magnetic matter distributed over its six faces in such a

manner that the density will be uniform over each face, and that the quantities of matter on the six faces will be as follows:—

$-il\,.\,\beta\gamma$, and $il\,.\,\beta\gamma$; on the two faces parallel to YOZ;
$-im\,.\,\gamma\alpha$, and $im\,.\,\gamma\alpha$; on the two faces parallel to ZOX;
$-in\,.\,\alpha\beta$, and $in\,.\,\alpha\beta$; on the two faces parallel to XOY.

Now if we consider adjacent parallelepipeds of equal dimensions, touching the six faces of the one we have been considering, we should find from each of them a second distribution of magnetic matter, to be placed upon that one of those six faces which it touches. Thus if we consider the first face $\beta\gamma$, or that of which the distance from YOZ is $x-\frac{1}{2}\alpha$; we shall have a second distribution upon it derived from a parallelepiped the coordinates of the centre of which are $x-\alpha$, y, z; and the quantity of matter in this second distribution will be

$$\left\{il+\frac{d(il)}{dx}(-\alpha)\right\}\beta\gamma.$$

This, added to that which was found above, gives

$$\frac{d(il)}{dx}(-\alpha)\,.\,\beta\gamma, \text{ or } -\frac{d(il)}{dx}\,.\,\alpha\beta\gamma$$

for the total amount of matter upon this face. Again, the quantity in the second distribution on the other face, $\beta\gamma$, is equal to

$$-\left\{il+\frac{d(il)}{dx}\,.\,\alpha\right\}\beta\gamma,$$

and therefore the total amount of matter on this face will be

$$-\frac{d(il)}{dx}\,.\,\alpha\beta\gamma.$$

By determining in a similar way the final quantities of matter on the other faces of the parallelepiped, we find that the total amount of matter to be distributed over its surface is

$$-2\left\{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}\right\}\alpha\beta\gamma.$$

Now as the parallelepipeds into which we imagine the whole mass divided are infinitely small, we may substitute a continuous distribution of matter through them, in place of the superficial distributions on their faces which have been determined; and in making this substitution, the quantity of matter which we must suppose to be spread through the interior of any one of them must be half the total quantity on its surface, since each of its faces is common to it and another parallelepiped. Hence the quantity of matter to be distributed through the parallelepiped $\alpha\beta\gamma$ is equal to

$$-\left\{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}\right\}\alpha\beta\gamma.$$

Besides this continuous distribution through the interior of the magnet, there must

be a superficial distribution to represent the neutralized polarity at its surface. If ρ denote the density of this distribution at any point; $[l]$, $[m]$, $[n]$ the direction cosines, and $[i]$ the intensity of the magnetization of the solid close to it; and λ, μ, ν the direction cosines of a normal to the surface, we shall have, as in the case of the uniformly magnetized solid previously considered,

$$\rho=[i]\cos\theta=[il].\lambda+[im].\mu+[in].\nu \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

If, according to the usual definition of "density," k denote the density of the magnetic matter at P, in the continuous distribution through the interior, the expression found above for the quantity of matter in the element α, β, γ, leads to the formula

$$k=-\left\{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}\right\}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

These two equations express respectively the superficial distribution, and the continuous distribution through the solid, of the magnetic matter which entirely represents the polarity of the given magnet. The fact that the quantity of northern matter is equal to the quantity of southern in the entire distribution, is readily verified by showing from these formulæ, as may readily be done by integration, that the total quantity of matter is algebraically equal to nothing.

43. If there be an abrupt change in the intensity or direction of the magnetization from one part of the magnetized substance to another, a slight modification in the formulæ given above will be convenient. Thus we may take a case differing very little from a given case, but which instead of presenting finite differences in the intensity or direction of magnetization, on the two sides of any surface in the substance of the magnet, has merely very sudden continuous changes in the values of those elements: we may conceive the distribution to be made more and more nearly the same as the given distribution, with its abrupt transitions, and we may determine the limit towards which the value of the expression (2) approximates, and thus, although according to the ordinary rules of the differential calculus this formula fails in the limiting case, we may still derive the true result from it. It is very easily shown in this way, that, besides the continuous distribution given by the expression (2) applied to all points of the substance for which it does not fail, there will be a superficial distribution of magnetic matter on any surface of discontinuity; and that the density of this superficial distribution will be the difference between the products of the intensity of magnetization into the cosine of the inclination of its direction to the normal, on the two sides of the surface.

44. This result, obtained by the interpretation of formula (2) in the extreme case, might have been obtained directly from the original investigation, by taking into account the abrupt variation of the magnetization at the surface of discontinuity, as we did the abrupt termination of the magnetized substance at the boundary of the magnet, and representing the un-neutralized polarity which results, by a superficial distribution of magnetic matter.

CHAPTER IV. *Determination of the Mutual Actions between any Given Portions of Magnetized Matter.*

45. The synthetical part of the theory of magnetism has for its ultimate object the determination of the total action between two magnets, when the distribution of magnetism in each is given. The principles according to which the data of such a problem may be specified have been already laid down (§§ 28–31.), and we have seen that, with sufficient data in any case, COULOMB's laws of magnetic force are sufficient to enable us to apply ordinary statical principles to the solution of the problem. Hence the elements of this part of the theory may be regarded as complete, and we may proceed to the mathematical treatment of the subject.

46. The investigations of the preceding chapter, which show us how we may conventionally represent any given magnet, in its agency upon other bodies, by an imaginary magnetic matter distributed on its surface and through its interior; enable us to reduce the problem of finding the action between any two magnets, to the known problem of determining the resultant of the attractions or repulsions exerted between the particles of two groups of matter, according to the law of force which is met with so universally in natural phenomena. The direct formulæ applicable for this object are so readily obtained by means of the elementary principles of statics, and so well known, that it is unnecessary to cite them here, and we may regard equations (1) and (2) of the preceding chapter (§ 42.) as sufficient for indicating the manner in which the details of the problem may be worked out in any particular case. The expression for the "potential," and other formulæ of importance in LAPLACE's method of treating this subject, are given below (§ 51.), as derived from the results expressed in equations (1) and (2).

47. The preceding solution of the problem, although extremely simple and often convenient, must be regarded as very artificial, since in it the resultant action is found by the composition of mutual actions between the particles of an imaginary magnetic matter, which are not the same as the real mutual actions between the different parts of the magnets themselves, although the resultant action between the entire groups of matter is necessarily the same as the real resultant action between the entire magnets. Hence it is very desirable to investigate another solution, of a less artificial form, in which the required resultant action may be obtained by compounding the real actions between the different parts into which we may conceive the magnets to be divided. The remainder of the chapter, after some preliminary explanations and definitions, will be devoted to this object.

48. The "resultant magnetic force at any point" is an expression which will very frequently be employed in what follows, and it is therefore of importance that its signification should be clearly defined. For this purpose, let us consider separately the cases of an external point in the neighbourhood of a magnet, and a point in space which is actually occupied by magnetic matter.

(1.) The resultant force at a point in space, void of magnetized matter, is the force that the north pole of a unit-bar (or a positive unit of imaginary magnetic matter), if placed at this point, would experience.

(2.) The resultant force at a point situated in space occupied by magnetized matter, is an expression the signification of which is somewhat arbitrary. If we conceive the magnetic substance to be removed from an infinitely small space round the point, the preceding definition would be applicable; since, if we imagine a very small bar-magnet to be placed in a definite position in this space, the force upon either end would be determinate. The circumstances of this case are made clear by considering the distribution of imaginary magnetic matter required to represent the given magnet, without the small portion we have conceived to be removed from its interior; which will differ from the distribution that represents the entire given magnet, in wanting the small portion of the continuous interior distribution corresponding to the removed portion, and in having instead a superficial distribution on the small internal surface bounding the hollow space. If we consider the portion removed to be infinitely small, the want of the small portion of the *solid* magnetic matter will produce no finite effect upon any point; but the superficial distribution at the boundary of the hollow space will produce a finite force upon any magnetic point within it. Hence the resultant force upon the given point round which the space was conceived to be hollowed, may be regarded as compounded of two forces, one due to the polarity of the complete magnet, and the other to the superficial polarity left free by the removal of the magnetized substance*. The former component is the force meant by the expression "the resultant force at a point within a magnetic substance," when employed in the present paper†.

49. The conventional language and ideas with reference to the imaginary magnetic

* If the portion removed be spherical and infinitely small, it may be proved that the force at any point within it, resulting from the free polarity of the solid at the surface bounding the hollow space, is in the direction of the lines of magnetization of the substance round it, and is equal to $\frac{4\pi i}{3}$. This theorem (due to Poisson) will be demonstrated at the commencement of the Theory of Magnetic Induction, because we shall have to consider the "magnetizing force" upon any small portion of an inductively magnetized substance as the actual resultant force that would exist within the hollow space that would be left if the portion considered were removed, and the magnetism of the remainder constrained to remain unaltered.

† If we imagine a magnet to be divided into two parts by any plane passing through the line of magnetization at any internal point, P, and if we imagine the two parts to be separated by an infinitely small interval and a unit north pole to be placed between them at P, the force which this pole would experience is "the resultant force at a point, P, of the magnetic substance." This is the most direct definition of the expression that could have been given, and it agrees with the definition I have actually adopted; but I have preferred the explanation and statement in the text, as being practically more simple, and more directly connected with the various investigations in which the expression will be employed.

[Note added June 15, 1850.—Some subsequent investigations on the comparison of common magnets and electro-magnets have altered my opinion, that the definition in the text is to be preferred; and I now believe the definition in the note to present the subject in the simplest possible manner, and in that which, for the applications to be made in the continuation of this Essay, is most convenient on the whole.]

matter, explained above (§§ 32–44), enable us to give the following simple statement of the definition, including both the cases which we have been considering.

The resultant magnetic force at any point, whether in the neighbourhood of a magnet or in its interior, is the force that a unit of northern magnetic matter would experience if it were placed at that point, and if all the magnetized substance were replaced by the corresponding distribution of imaginary magnetic matter.

50. The determination of the resultant force at any point is, as we shall see, much facilitated by means of a method first introduced by LAPLACE in the mathematical treatment of the theory of attraction, and developed to a very remarkable extent by GREEN in his "Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism" (Nottingham, 1828), and in his other writings on the same and on allied subjects in the Cambridge Philosophical Transactions, and in the Transactions of the Royal Society of Edinburgh. LAPLACE'S fundamental theorem is so well known that it is unnecessary to demonstrate it here; but for the sake of reference, the following enunciation of it is given. The term "potential," defined in connection with it, was first introduced by GREEN in his Essay (1828). It was at a later date introduced independently by GAUSS, and is now in very general use.

Theorem (LAPLACE).—The resultant force produced by a body, or a group of attracting or repelling particles, upon a unit particle placed at any point P, is such that the difference between the values of a certain function, at any two points p and p' infinitely near P, divided by the distance pp', is equal to its component in the direction of the line joining p and p'.

Definition (GREEN).—This function, which, for a given mass, has a determinate value at any point, P, of space, is called the potential of the mass, at the point P.

It follows from the general demonstration, that, when the law of force is that of the inverse square of the distance, the potential is found by dividing the quantity of matter in any infinitely small part of the mass, by its distance from P, and adding all the quotients so obtained.

51. The same demonstration is applicable to prove, in virtue of COULOMB'S fundamental laws of magnetic force, the same theorem with reference to any kind of magnet that can be conceived to be composed of uniformly magnetized bars, either finite or infinitely small, put together in any way, that is, of any magnet other than an electro-magnet; and the investigation, in the preceding chapter, of the resulting distribution of magnetic matter that may be imagined as representing in the simplest possible way the polarity of such a magnet, enables us to determine at once, from equations (1) and (2) of § 42, its potential at any point. Thus if V denote the potential at a point P, whose coordinates are ξ, η, ζ, and if dS denote an element of the surface of the magnet, situated at a point whose coordinates are $[x]$, $[y]$, $[z]$, we have, by the proposition enunciated at the end of § 49,—

$$V=\iint \frac{[il]\lambda+[im]\mu+[in]\nu}{[\Delta]}dS-\iiint \frac{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}}{\Delta}dxdydz, \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where Δ and $[\Delta]$ are respectively the distances of the points x, y, z and $[x, y, z]$ from the point P, and are given by the equations

$$\Delta^2=(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2$$
$$[\Delta]^2=(\xi-[x])^2+(\eta-[y])^2+(\zeta-[z])^2.$$

The double and triple integrals in the first and second terms of this expression are to be taken respectively over the whole surface bounding the magnet, and throughout the entire magnetized substance. Since, as is easily shown, the value of that portion of the triple integral in the second member which corresponds to an infinitely small portion of the solid containing (ξ, η, ζ), when this point is internal, is infinitely small, it follows that the magnetic force at any internal point, as defined in § 48, is derivable from a potential expressed by equation (3).

52. The expressions for the resultant force at any point, and its direction, may be immediately obtained when the potential function has been determined, by the rules of the differential calculus. Thus, if V has been determined in terms of the rectangular coordinates, ξ, η, ζ, of the point P, the three components, X, Y, Z, of the resultant force on this point will be given, in virtue of LAPLACE'S fundamental theorem enunciated in § 50, by the formulæ,

$$X=-\frac{dV}{d\xi}, \quad Y=-\frac{dV}{d\eta}, \quad Z=-\frac{dV}{d\zeta} \quad \ldots\ldots\ldots (4),$$

where the negative signs are introduced, because the potential is estimated in such a way that it diminishes in the direction along which a north pole is urged. If we take the expression (3) for V, and actually differentiate with reference to ξ, η, ζ under the integral signs, we obtain expressions for X, Y, and Z which agree with the expressions that might have been obtained directly, by means of the first principles of statics (see § 46), and thus the theorem is verified. Such a verification, extended so as to be applicable to a body acting according to any law of force, constitutes virtually the ordinary demonstration of the theorem.

53. The formulæ of the preceding paragraphs are applicable for the determination of the potential, and the resultant force at any point, whether within the magnetized substance or not, according to the general definition of § 49. The case of a point in the magnetized substance, according to the conventional second definition of § 48, cannot present itself in problems with reference to the mutual action between two actual magnets. This case being therefore excluded, we may proceed to the investigations indicated in § 47.

54. In the method which is now to be followed, the magnetized substances considered must be conceived to be divided into an infinite number of infinitely small parts, and the actual magnetism of each part will be taken into account, whether in determining the potential of the magnet at a given external point, or in investigating the mutual action between two magnets. In the first place, let us determine the potential due to an infinitely small element of a magnetized substance, and for this purpose we may commence by considering an infinitely thin, uniformly magnetized

bar of finite length. If m denote the strength of the bar, and if N and S be its north and south poles respectively, its potential at any point, P, will be, according to §§ 34 and 50,

$$\frac{m}{\mathrm{NP}}-\frac{m}{\mathrm{SP}}.$$

Let Δ denote the distance of the point of bisection of the bar from P, and θ the angle between this line and the direction of the bar measured from its centre towards its north pole. Then, if a be the length of the bar, the expression for the potential becomes

$$m\left\{\frac{1}{(\Delta^2-a\Delta\cos\theta+\frac{1}{4}a^2)^{\frac{1}{2}}}-\frac{1}{(\Delta^2+a\Delta\cos\theta+\frac{1}{4}a)^{\frac{1}{2}}}\right\}.$$

By expanding this in ascending powers of a, and neglecting all the terms after the first, we find for the potential of an infinitely small bar magnet,

$$\frac{ma\cos\theta}{\Delta^2}.$$

If now we suppose any number of such bar-magnets to be put together so as to constitute a mass magnetized in parallel lines, infinitely small in all its dimensions, the values of θ and Δ, and consequently the value of $\frac{\cos\theta}{\Delta^2}$, will be infinitely nearly the same for all of them, and the product of this into the sum of the values of ma for all the bar-magnets will express the potential of the entire mass. Hence, if the total magnetic moment be denoted by μ, the potential will be equal to

$$\frac{\mu\cos\theta}{\Delta^2}.$$

Now if we conceive the bars to have been arranged so as to constitute a uniformly magnetized mass, occupying a volume φ, we should have (§ 30.) for the intensity of magnetization, $i=\frac{\mu}{\varphi}$. Hence if φ denote the volume of an infinitely small element of uniformly magnetized matter, and i the intensity of its magnetization, the potential which it produces at any point P, at a finite distance from it, will be

$$\frac{i\varphi.\cos\theta}{\Delta^2},$$

where Δ denotes the distance of P from any point, E, within the element, and θ the angle between E P and a line drawn through E, in the direction of magnetization of the element, *towards the side of it which has northern polarity*.

55. Let us now suppose the element E to be a part of a magnet of finite dimensions, of which it is required to determine the total potential at an external point, P. Let ξ, η, ζ be the coordinates of P, referred to a system of rectangular axes, and let x, y, z be those of E. We shall have

$$\Delta^2=(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2;$$

and, if l, m, n denote the direction cosines of the magnetization at E,

$$\cos\theta = l\frac{\xi-x}{\Delta}+m\frac{\eta-y}{\Delta}+n\frac{\zeta-z}{\Delta}.$$

Hence the expression for the potential of the element E becomes

$$\frac{i\phi\{l(\xi-x)+m(\eta-y)+n(\zeta-z)\}}{\{(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2\}^{\frac{3}{2}}}.$$

Now the potential of a whole is equal to the sum of the potentials of all its parts, and hence, if we take $\phi = dx\,dy\,dz$, we have, by the integral calculus, the expression,

$$V=\iiint\frac{il.(\xi-x)+im.(\eta-y)+in.(\zeta-z)}{\{(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2\}^{\frac{3}{2}}}dxdydz \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

for the potential at the point P, due to the entire magnet*.

56. This expression is susceptible of a very remarkable modification, by integration by parts. Thus we may divide the second member into three terms, of which the following is one:

$$\iiint\frac{il.(\xi-x)dx}{\{(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2\}^{\frac{3}{2}}}dydz.$$

Integrating here by parts, with reference to x, we obtain

$$\left[\iint\frac{il.dy\,dz}{\Delta}\right]-\iiint\frac{\frac{d(il)}{dx}}{\Delta}dxdydz,$$

where the brackets enclosing the double integral denote that the variables in it must belong to some point of the surface. If λ, μ, ν denote the direction cosines of a normal to the surface at any point $[\xi, \eta, \zeta]$, and dS an element of the surface, we may take $dy\,dz=\lambda.dS$, and hence the double integral is reduced to

$$\iint\frac{[il]\lambda.dS}{[\Delta]};$$

and, as we readily see by tracing the limits of the first integral with reference to x, for all possible values of y and z this double integral must be extended over the entire surface of the magnet. By treating in a similar manner the other two terms of the preceding expression for V, we obtain, finally,

$$V=\iint\frac{[il]\lambda+[im]\mu+[in]\nu}{[\Delta]}dS-\iiint\frac{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}}{\Delta}dxdydz.$$

The second member of this equation is the expression for the potential of a certain complex distribution of matter, consisting of a superficial distribution, and a continuous internal distribution. The superficial-density of the distribution on the surface,

* From the form of definition given in the second foot-note on § 48, for the magnetic force at an internal point, it may be shown that the expression (5), as well as the expression (3), is applicable to the potential at any point, whether internal or external. The same thing may be shown by proving, as may easily be done, that the investigation of § 56 does not fail or become nugatory when (ξ, η, ζ) is included in the limits of integration.

and the density of the continuous distribution at any internal point, are expressed respectively by $[il]\lambda+[im]\mu+[in]\nu$, and $-\left\{\frac{d(il)}{dx}+\frac{d(im)}{dy}+\frac{d(in)}{dz}\right\}$. Hence we infer that the action of the complete magnet upon any external point is the same as would be produced by a certain distribution of imaginary magnetic matter, determinable by means of these expressions, when the actual distribution of magnetism in the magnet is given*. The demonstration of the same theorem, given above (§ 42), illustrates in a very interesting manner the process of integration by parts applied to a triple integral.

57. The mutual action of any two magnets, considered as the resultant of the mutual actions between the infinitely small elements into which we may conceive them to be divided, consists of a force and a couple of which the components will be expressed by means of six triple integrals. Simpler expressions for the same results may be obtained by employing a notation for subsidiary results derived from triple integration with reference to one of the bodies, in the following manner.

58. Let us in the first place determine the action exerted by a given magnet, upon an infinitely thin, uniformly and longitudinally magnetized bar, placed in a given position in its neighbourhood.

We may suppose the rectangular coordinates, ξ, η, ζ, of the north pole, and ξ', η', ζ' of the south pole of the bar to be given, and hence the components, X, Y, Z and X', Y', Z', of the resultant forces, at those points, due to the other given magnet, may be regarded as known. Then, if β denote the "strength" of the bar-magnet, the components of the forces on its two poles will be respectively,

$$\beta X, \beta Y, \beta Z, \text{ on the point } (\xi, \eta, \zeta),$$

and

$$-\beta X', -\beta Y', -\beta Z', \text{ on the point } (\xi', \eta', \zeta').$$

The resultant action due to this system of forces may be determined by means of the elementary principles of statics. Thus if we conceive the forces to be transferred to the middle of the bar by the introduction of couples, the system will be reduced to a force, on this point, whose components are

$$\beta(X-X'), \quad \beta(Y-Y'), \quad \beta(Z-Z'),$$

and a couple, whose components are

$$\left\{\beta(Z+Z').\frac{1}{2}(\eta-\eta')-\beta(Y+Y').\frac{1}{2}(\zeta-\zeta')\right\},$$

$$\left\{\beta(X+X').\frac{1}{2}(\zeta-\zeta')-\beta(Z+Z').\frac{1}{2}(\xi-\xi')\right\},$$

$$\left\{\beta(Y+Y').\frac{1}{2}(\xi-\xi')-\beta(X+X').\frac{1}{2}(\eta-\eta')\right\}.$$

* This very remarkable theorem is due to Poisson, and the demonstration, as it has been just given in the text, is to be found in his first memoir on Magnetism. The demonstration which I have given in § 42 may be regarded as exhibiting, by the theory of polarity, the physical principles expressed in the analytical formulæ.

59. If l, m, n denote the direction cosines of a line drawn along the bar, from its middle towards its north pole, and if a be the length of the bar, we shall have

$$\xi-\xi'=al,\quad \eta-\eta'=am,\quad \zeta-\zeta'=an.$$

Hence, if the bar be infinitely short, and if x, y, z denote the coordinates of its middle point, we have

$$X-X'=\frac{dX}{dx}.al+\frac{dX}{dy}.am+\frac{dX}{dz}.an,$$

$$Y-Y'=\frac{dY}{dx}.al+\frac{dY}{dy}.am+\frac{dY}{dz}.an,$$

and

$$Z-Z'=\frac{dZ}{dx}.al+\frac{dZ}{dy}.am+\frac{dZ}{dz}.an.$$

Multiplying each member of these equations by β, we obtain the expressions for the components of the force in this case; and the expressions for the components of the couples are found in their simpler forms, by substituting for $\xi-\xi'$, &c. their values given above; and, on account of the infinitely small factor which each term contains, taking $2X$, $2Y$, and $2Z$, in place of $X+X'$, $Y+Y'$, and $Z+Z'$.

60. Let us now suppose an infinite number of such infinitely small bar-magnets to be put together so as to constitute a mass, infinitely small in all its dimensions, uniformly magnetized in the direction (l, m, n) to such an intensity that its magnetic moment is μ. We infer, from the preceding investigation, that the total action on this body, when placed at the point x, y, z, will be composed of a force whose components are

$$\mu\left(\frac{dX}{dx}l+\frac{dX}{dy}m+\frac{dX}{dz}n\right),$$

$$\mu\left(\frac{dY}{dx}l+\frac{dY}{dy}m+\frac{dY}{dz}n\right),$$

$$\mu\left(\frac{dZ}{dx}l+\frac{dZ}{dy}m+\frac{dZ}{dz}n\right),$$

acting at the centre of gravity of the solid supposed homogeneous; and a couple of which the components are

$$\mu(Zm-Yn),$$
$$\mu(Xn-Zl),$$
$$\mu(Yl-Xm).$$

61. The preceding investigation enables us, by means of the integral calculus, to determine the total mutual action between any two given magnets. For, if we take X, Y, Z to denote the components of the resultant force due to one of the magnets, at any point (x, y, z) of the other, and if i denote the intensity and (l, m, n) the direction of magnetization of the substance of the second magnet at this point, we may take $\mu=i.dxdydz$ in the expressions which were obtained, and they will then express

the action which one of the magnets exerts upon an element $dxdydz$ of the other. To determine the total resultant action, we may transfer all the forces to the origin of coordinates, by introducing additional couples; and, by the usual process, we find, for the mutual action between the two magnets, a force in a line through this point, and a couple, of which the components, F, G, H, and L, M, N, are given by the equations

$$\left.\begin{aligned} \mathrm{F} &= \iiint \left(il\frac{d\mathrm{X}}{dx} + im\frac{d\mathrm{X}}{dy} + in\frac{d\mathrm{X}}{dz} \right) dxdydz \\ \mathrm{G} &= \iiint \left(il\frac{d\mathrm{Y}}{dx} + im\frac{d\mathrm{Y}}{dy} + in\frac{d\mathrm{Y}}{dz} \right) dxdydz \\ \mathrm{H} &= \iiint \left(il\frac{d\mathrm{Z}}{dx} + im\frac{d\mathrm{Z}}{dy} + in\frac{d\mathrm{Z}}{dz} \right) dxdydz \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\left.\begin{aligned} \mathrm{L} &= \iiint \left\{ im\mathrm{Z} - in\mathrm{Y} + y\left(il\frac{d\mathrm{Z}}{dx} + im\frac{d\mathrm{Z}}{dy} + in\frac{d\mathrm{Z}}{dz} \right) - z\left(il\frac{d\mathrm{Y}}{dx} + im\frac{d\mathrm{Y}}{dy} + in\frac{d\mathrm{Y}}{dz} \right) \right\} dxdydz \\ \mathrm{M} &= \iiint \left\{ in\mathrm{X} - il\mathrm{Z} + z\left(il\frac{d\mathrm{X}}{dx} + im\frac{d\mathrm{X}}{dy} + in\frac{d\mathrm{X}}{dz} \right) - x\left(il\frac{d\mathrm{Z}}{dx} + im\frac{d\mathrm{Z}}{dy} + in\frac{d\mathrm{Z}}{dz} \right) \right\} dxdydz \\ \mathrm{N} &= \iiint \left\{ il\mathrm{Y} - im\mathrm{X} + x\left(il\frac{d\mathrm{Y}}{dx} + im\frac{d\mathrm{Y}}{dy} + in\frac{d\mathrm{Y}}{dz} \right) - y\left(il\frac{d\mathrm{X}}{dx} + im\frac{d\mathrm{X}}{dy} + in\frac{d\mathrm{X}}{dz} \right) \right\} dxdydz \end{aligned}\right\} \quad (7)$$

62. If, in the second members of these equations, we employ for X, Y, Z respectively their values obtained, as indicated in equations (4) of § 52, by the differentiation of the expression (5) for V in § 55, we obtain expressions for F, G, H, L, M, N, which may readily be put under symmetrical forms with reference to the two magnets, exhibiting the parts of those quantities depending on the mutual action between an element of one of the magnets, and an element of the other. Again, expressions exhibiting the mutual action between any element of the imaginary magnetic matter of one magnet, and any element of the imaginary magnetic matter of the other, may be found by first modifying by integration by parts, as in § 56, from the expressions which we have actually obtained for F, G, H, L, M, N; and then substituting for X, Y, and Z their values obtained by the differentiation of the expression (3) for V.

It is unnecessary here to do more than indicate how such other formulæ may be derived from those given above; for whenever it may be required, there can be no difficulty in applying the principles which have been established in this paper to obtain any desired form of expression for the mutual action between two given magnets.

§§ 63 and 64*. *On the Expression of Mutual Action between two Magnets by means of the Differential Coefficients of a Function of their relative Position.*

63. By a simple application of the theory of the potential, it may be shown that the amount of mechanical work spent or gained in any motion of a permanent magnet, effected under the action of another permanent magnet in a fixed position, depends solely on the initial and final positions, and not at all upon the positions successively occupied by the magnet in passing from one to the other. Hence the amount of work requisite to bring a given magnet from being infinitely distant from all magnetic bodies, into a certain position in the neighbourhood of a given fixed magnet, depends solely upon the distributions of magnetism in the two, and on the relative position which they have acquired. Denoting this amount by Q, we may consider Q as a function of coordinates which fix the relative position of the two magnets; and the variation which Q experiences when this is altered in any way will be the amount of work spent or lost, as the case may be, in effecting the alteration. This enables us to express completely the mutual action between the two magnets, by means of differential coefficients of Q, in the following manner:—

If we suppose one of the magnets to remain fixed during the alterations of relative position conceived to take place, the quantity Q will be a function of the linear and angular coordinates by which the variable position of the other is expressed. Without specifying any particular system of coordinates to be adopted, we may denote by $d_\xi Q$ the augmentation of Q when the moveable magnet is pushed through an infinitely small space $d\xi$ in any given direction, and by $d_\varphi Q$ the augmentation of Q when it is turned round any given axis, through an infinitely small angle $d\varphi$. Then, if F denote the force upon the magnet in the direction of $d\xi$, and L the moment round the fixed axis of all the forces acting upon it (or the component, round the fixed axis, of the resultant couple obtained when all the forces on the different parts of the magnet are transferred to any point on this axis), we shall have

$$-\mathrm{F}d\xi = d_\xi \mathrm{Q}, \quad \text{and} \quad -\mathrm{L}d\varphi = d_\varphi \mathrm{Q},$$

since a force equal to $-\mathrm{F}$ is overcome through the space $d\xi$ in the first case, and a couple, of which the moment is equal to $-\mathrm{L}$, is overcome through an angle $d\varphi$ in the second case of motion. Hence we have

$$\mathrm{F} = -\frac{d_\xi \mathrm{Q}}{d\xi}$$

$$\mathrm{L} = -\frac{d_\varphi \mathrm{Q}}{d\varphi}.$$

64. It only remains to show how the function Q may be determined when the distributions of magnetism in the two magnets and the relative positions of the bodies are

* Communicated June 20, 1850.

given. For this purpose, let us consider points P and P′, in the two magnets respectively, and let their coordinates with reference to three fixed rectangular axes be denoted by x, y, z and x', y', z'; let also the intensity of magnetization at P be denoted by i, and its direction cosines by l, m, n; and let the corresponding quantities, with reference to P′, be denoted by i', l', m', n'. Then it may be demonstrated without difficulty that

$$Q=\iiiiii dx\,dy\,dz\,dx'\,dy'\,dz'\,ii'\left\{ll'\frac{d^2\frac{1}{\Delta}}{dx\,dx'}+lm'\frac{d^2\frac{1}{\Delta}}{dx\,dy'}+ln'\frac{d^2\frac{1}{\Delta}}{dx\,dz'}\right.$$
$$+ml'\frac{d^2\frac{1}{\Delta}}{dy\,dx'}+mm'\frac{d^2\frac{1}{\Delta}}{dy\,dy'}+mn'\frac{d^2\frac{1}{\Delta}}{dy\,dz'}$$
$$\left.+nl'\frac{d^2\frac{1}{\Delta}}{dz\,dx'}+nm'\frac{d^2\frac{1}{\Delta}}{dz\,dy'}+nn'\frac{d^2\frac{1}{\Delta}}{dz\,dz'}\right\},$$

where, for brevity, Δ is taken to denote $\{(x-x')^2+(y-y')^2+(z-z')^2\}^{\frac{1}{2}}$, and the differentiations upon $\frac{1}{\Delta}$ are merely indicated. Now, by any of the ordinary formulæ for the transformation of coordinates, the values of x, y, z, and x', y', z', may be expressed in terms of coordinates of the point P with reference to axes fixed in the magnet to which it belongs, of the coordinates of the point P′ with reference to axes fixed in the other, and of the coordinates adopted to express the relative position of the two magnets: and so the preceding expression for Q may be transformed into an expression involving explicitly the relative coordinates, and containing the coordinates of the points P and P′ in the two bodies only as variables in integrations, the limits of which, depending only on the forms and dimensions of the two bodies, are absolutely constant. Thus Q is obtained as a function of the relative coordinates of the bodies, and the solution of the problem is complete.

There is no difficulty in working out the result by this method, so as actually to obtain either the expressions (6) and (7) of § 61, or the expressions indicated in § 62, although the process is somewhat long.

The method just explained for expressing the mutual action between two magnets in terms of a function of their relative position, has been added to this chapter rather for the sake of completing the mathematical theory of the division of the subject to which it is devoted, than for its practical usefulness in actual problems regarding magnetic force, for which the most convenient solutions may generally be obtained by some of the more synthetical methods explained in the preceding parts of the chapter. There is however a far more important application of the principles upon which this last method is founded which remains to be made. The mechanical value of a distribu-

tion of magnetism, although it has not, I believe, been noticed in any writings hitherto published on the mathematical theory of magnetism, is a subject of investigation of great interest, and, as I hope on a later occasion to have an opportunity of showing, of much consequence, on account of its maximum and minimum problems, which lead to demonstrations of important theorems in the solutions of inverse problems regarding magnetic distribution.

XI. *A Mathematical Theory of Magnetism.—Continuation of Part* I. *By* WILLIAM THOMSON, *Esq., M.A., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow. Communicated by Lieut.-Colonel* SABINE, *For. Sec. R.S.*

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CHAPTER V. *On Solenoidal and Lamellar Distributions of Magnetism.*

65. IN the course of some researches upon inverse problems regarding distributions of magnetism, and upon the comparison of electro-magnets and common magnets, I have found it extremely convenient to make use of definite terms to express certain distributions of magnetism and forms of magnetized matter possessing remarkable properties. The use of such terms will be of still greater consequence in describing the results of these researches, and therefore, before proceeding to do so, I shall give definitions of the terms which I have adopted, and explain briefly the principal properties of the magnetic distributions to which they are applied. The remainder of this chapter will be devoted to three new methods of analysing the expressions for the resultant force of a magnet at any point, suggested by the consideration of these special forms of magnetic distribution. A Mathematical Theory of Electro-Magnets, and Inverse Problems regarding magnetic distributions, are the subjects of papers which I hope to be able to lay before the Royal Society on a subsequent occasion.

66. *Definitions and explanations regarding Magnetic Solenoids.*

(1.) A magnetic solenoid* is an infinitely thin bar of any form, longitudinally magnetized with an intensity varying inversely as the area of the normal section in different parts.

The constant product of the intensity of magnetization into the area of the normal section, is called the magnetic strength, or sometimes simply the strength of the solenoid. Hence the magnetic moment of any straight portion, or of an infinitely small portion of a curved solenoid, is equal to the product of the magnetic strength into the length of the portion.

(2.) A number of magnetic solenoids of different lengths may be put together so

* This term (from σωλήν, *a tube*,) is suggested by the term "electro-dynamic solenoid" applied by AMPÈRE to a certain tube-like arrangement of galvanic circuits which produces precisely the same external magnetic effect as is produced by ordinary magnetism distributed in the manner defined in the text. The especial appropriateness of the term to the magnetic distribution is manifest from the relation indicated in the foot-note on § 76 below, between the intensity and direction of magnetization in a solenoid, and the velocity and direction of motion of a liquid flowing through a tube of constant or varying section.

as to constitute what is, as far as regards magnetic action, equivalent to a single infinitely thin bar of any form, longitudinally magnetized with an intensity varying arbitrarily from one end of the bar to the other. Hence such a magnet may be called a complex magnetic solenoid.

The magnetic strength of a complex solenoid is not uniform, but varies from one part to another.

(3.) An infinitely thin closed ring, magnetized in the manner described in (1.), is called a closed magnetic solenoid.

67. *Definitions and explanations regarding Magnetic Shells.*

(1.) A magnetic shell is an infinitely thin sheet of any form, normally magnetized with an intensity varying inversely as the thickness in different parts.

The constant product of the intensity of magnetization into the thickness is called the magnetic strength, or sometimes simply the strength of the shell. Hence the magnetic moment of any plane portion, or of an infinitely small portion of a curved magnetic shell, is equal to the product of the magnetic strength, into the area of the portion.

(2.) A number of magnetic shells of different areas may be put together so as to constitute what is, as far as regards magnetic action, equivalent to a single infinitely thin sheet of any form, normally magnetized with an intensity varying arbitrarily over the whole sheet. Hence such a magnet may be called a complex magnetic shell.

The magnetic strength of a complex shell is not uniform, but varies from one part to another.

(3.) An infinitely thin sheet, of which the two sides are closed surfaces, is called a closed magnetic shell.

68. *Solenoidal and Lamellar Distributions of Magnetism.*—If a finite magnet of any form be capable of division into an infinite number of solenoids which are either closed or have their ends in the bounding surface, the distribution of magnetism in it is said to be solenoidal, and the substance is said to be solenoidally magnetized.

If a finite magnet of any form be capable of division into an infinite number of magnetic shells which are either closed or have their edges in the bounding surface, the distribution of magnetism in it is said to be lamellar*, and the substance is said to be lamellarly magnetized.

69. *Complex Lamellar Distributions of Magnetism.*—If a finite magnet of any form be capable of division into an infinite number of complex magnetic shells, it is said to possess a complex lamellar distribution of magnetism.

70. *Complex Solenoidal Distributions of Magnetism.*—Since, by cutting it along

* The term *lamellar*, adopted for want of a better, is preferred to "laminated"; since this might be objected to as rather meaning "composed of plates," than *composed of shells*, whether plane or curved, and is besides too much associated with a mechanical structure such as that of slate or mica, to be a convenient term for the magnetic distributions defined in the text.

lines of magnetization, every magnet of finite dimensions may be divided into an infinite number of longitudinally magnetized infinitely thin bars or rings, any distribution of magnetism which is not solenoidal might be called a complex solenoidal distribution; but no advantage is obtained by the use of this expression, which is only alluded to here, on account of the analogy with the subject of the preceding definition.

71. Prop.—*The action of a magnetic solenoid is the same as if a quantity of positive or northern imaginary magnetic matter numerically equal to its magnetic strength, were placed at one end, and an equal absolute quantity of negative or southern matter at the other end.*

The truth of this proposition follows at once from the investigation of Chap. III. §§ 36, 37, 38.

Cor. 1.—The action of a magnetic solenoid is independent of its form, and depends solely on its strength and the positions of its extremities.

Cor. 2.—A closed solenoid exerts no action on any other magnet.

Cor. 3.—The "resultant force" (defined in Chap. IV. § 49) at any point in the substance of a closed magnetic solenoid vanishes.

72. Prop.—*If* i *be the intensity of magnetization, and* ω *the area of the normal section at any point* P, *at a distance* s *from one extremity of a complex solenoid, and if* $[i\omega]$ *and* $\{i\omega\}$ *denote the values of the product of these quantities at the extremity from which* s *is measured, and at the other extremity respectively; the magnetic action will be the same as if there were a distribution of imaginary magnetic matter, through the length of the bar of which the quantity in an infinitely small portion* ds, *of the length at the point* P, *would be* $-\frac{d(i\omega)}{ds}ds$, *and accumulations of quantities equal to* $-[i\omega]$ *and* $\{i\omega\}$ *respectively at the two extremities.*

The truth of this proposition follows immediately from the conclusions of Chap. III. § 38.

73. Prop.—*The potential of a magnetic shell at any point is equal to the solid angle which it subtends at that point multiplied by its magnetic strength**.

Let dS denote the area of an infinitely small element of the shell, Δ the distance of this element from the point P, at which the potential is considered, and θ the angle between this line, and a normal to the shell drawn through the north polar side of dS. Then if λ denote the magnetic strength of the shell, the magnetic moment of the element dS will be $\lambda\, dS$, and (§ 54.) the potential due to it at P will be

$$\frac{\lambda dS \cdot \cos\theta}{\Delta^2}.$$

* This theorem is due to Gauss (see his paper "On the General Theory of Terrestrial Magnetism," § 38; of which a translation is published in Taylor's Scientific Memoirs, vol. ii.). Ampère's well-known theorem, referred to by Gauss, that a closed galvanic circuit produces the same magnetic effect as a magnetic shell of any form having the circuit for its edge, implies obviously the truth of the first part of Cor. 2 below.

Now $\frac{dS \cdot \cos\theta}{\Delta^2}$ is the solid angle subtended at P by the element dS, and therefore the potential due to any infinitely small element is equal to the product of its magnetic strength, into the solid angle which its area subtends at P. But the potential due to the whole is equal to the sum of the potentials due to the parts, and the strength is the same for all the parts. Hence the potential due to the whole shell is equal to the product of its strength into the sum of the solid angles which all its parts, or the solid angle which the whole, subtends at P.

Cor. 1.—The expression $\frac{dS \cdot \cos\theta}{\Delta^2}$, which occurred in the preceding demonstration, being positive or negative according as θ is acute or obtuse, it appears that the solid angles subtended by different parts of the shell at P must be considered as positive or negative according as their north polar or their south polar sides are towards this point.

Cor. 2.—The potential at any point due to a magnetic shell is independent of the form of the shell itself, and depends solely on its bounding line or edge, subject to an ambiguity, the nature of which is made clear by the following statement:—

If two shells of equal magnetic strength, λ, have a common boundary, and if the north polar side of one, and the south polar side of the other be towards the enclosed space, the potentials due to them at any external point will be equal; and the potential at any point in the enclosed space, due to that one of which the northern polarity is on the inside, will exceed the potential due to the other by the constant $4\pi\lambda$.

Cor. 3.—Of two points infinitely near one another on the two sides of a magnetic shell, but not infinitely near its edge, the potential at that one which is on the north polar side exceeds the potential at the other by the constant $4\pi\lambda$.

Cor. 4.—The potential of a closed magnetic shell of strength λ, with its northern polarity on the inside, is $4\pi\lambda$, for all points in the enclosed space, and 0 for all external points; and for points in the magnetized substance it varies continuously from the inside, where it is $4\pi\lambda$ to the outside, where it is 0.

Cor. 5.—A closed magnetic shell exerts no force on any other magnet.

Cor. 6.—The "resultant force" (§ 49.) at any point in the substance of a closed magnetic shell is equal to $\frac{4\pi\lambda}{\tau}$, if τ be the thickness, or to $4\pi i$, if i be the intensity of magnetization of the shell in the neighbourhood of the point, and is in the direction of a normal drawn from the point through the south polar side of the shell.

Cor. 7.—If the intensity of magnetization of an open shell be finite, the resultant force at any external point not infinitely near the edge is infinitely small; but the force at any point in the substance not infinitely near the edge is finite, and is equal to $4\pi i$, if i be the intensity of the magnetization in the neighbourhood of the point, and is in the direction of a normal through the south polar side.

74. Prop.—*A distribution of magnetism expressed by* $\{(\alpha, \beta, \gamma)$ at $(x, y, z)\}$* *is solenoidal if, and is not solenoidal unless* $\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0$.

The condition that a given distribution of magnetism, in a substance of finite dimensions, may be solenoidal, is readily deduced from the investigations of § 42, by means of the propositions of §§ 71 and 72. For, if the distribution of magnetism be solenoidal, the imaginary magnetic matter by which the polarity of the whole magnet may be represented will be situated at the ends of the solenoids, according to § 71, and therefore (§ 68.) will be spread over the bounding surface. On the other hand, if the distribution be not solenoidal, that is, if the magnet be divisible into solenoids, of which some, if not all, are complex; there will, according to § 72, be an internal distribution of imaginary magnetic matter in the representation of the polarity of the whole magnet. Hence it follows from § 42, that if α, β, γ denote the components of the intensity of magnetization at any internal point (x, y, z), the equation

$$\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0 \quad . \quad . \quad .

not lamellar unless $\alpha dx+\beta dy+\gamma dz$ *is the differential of a function of three independent variables.*

Let ψ be a variable which has a certain value for each of the series of surfaces by which the magnet may be divided into magnetic shells; so that, if ψ be considered as a function of x, y, z, any one of these surfaces will be represented by the equation

$$\psi(x, y, z)=\Pi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a);$$

and the entire series will be obtained by giving the parameter, Π, successively a series of values each greater than that which precedes it by an infinitely small amount. According to the definition of a magnetic shell (§ 67.), the lines of magnetization must cut these surfaces orthogonally; and hence, since α, β, γ denote quantities proportional to the direction cosines of the magnetization at any point, we must have

$$\frac{\alpha}{\frac{d\psi}{dx}}=\frac{\beta}{\frac{d\psi}{dy}}=\frac{\gamma}{\frac{d\psi}{dz}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b).$$

Let us consider the magnetic shell between two of the consecutive surfaces corresponding to values of the parameter of which the infinitely small difference is ϖ. The thickness of this shell at any point (x, y, z) will be

$$\frac{\varpi}{\left(\frac{d\psi^2}{dx^2}+\frac{d\psi^2}{dy^2}+\frac{d\psi^2}{dz^2}\right)^{\frac{1}{2}}}.$$

Now the product of the intensity of magnetization, into the thickness of the shell, must be constant for all points of the same shell; and hence, since ϖ is constant, and since α, β, γ denote quantities such that $(\alpha^2+\beta^2+\gamma^2)^{\frac{1}{2}}$ is the intensity of magnetization at any point, we must have

$$\frac{(\alpha^2+\beta^2+\gamma^2)^{\frac{1}{2}}}{\left(\frac{d\psi^2}{dx^2}+\frac{d\psi^2}{dy^2}+\frac{d\psi^2}{dz^2}\right)^{\frac{1}{2}}}=F(\psi) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c),$$

where $F(\psi)$ denotes a quantity which is constant when ψ is constant. This equation, and the two equations (b), express all the conditions required to make the given distribution lamellar. By combining them we obtain the following three, which are equivalent to them:—

$$\alpha=F(\psi)\frac{d\psi}{dx}, \quad \beta=F(\psi)\frac{d\psi}{dy}, \quad \gamma=F(\psi)\frac{d\psi}{dz};$$

and hence, if $\int F(\psi)d\psi$ be denoted by φ, we have

$$\alpha=\frac{d\varphi}{dx}, \quad \beta=\frac{d\varphi}{dy}, \quad \gamma=\frac{d\varphi}{dz} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (II.),$$

where φ is some function of x, y and z. Hence the condition that a magnetic distribution (α, β, γ) may be lamellar, is simply that $\alpha dx+\beta dy+\gamma dz$ must be the differential of a function of three independent variables. The equations to express this are

obtained in their simplest forms by eliminating the arbitrary function φ by differentiation; and are of course

$$\left.\begin{aligned}\frac{d\beta}{dz}-\frac{d\gamma}{dy}&=0\\ \frac{d\gamma}{dx}-\frac{d\alpha}{dz}&=0\\ \frac{d\alpha}{dy}-\frac{d\beta}{dx}&=0\end{aligned}\right\}\quad\text{(III.)}$$

Cor.—It follows from the first part of the preceding investigation that equations (*b.*) express that the distribution, if not lamellar, is complex-lamellar. By eliminating the arbitrary function ψ from those equations, (which merely express that $\alpha dx+\beta dy+\gamma dz$ is integrable by a factor,) we obtain the well-known equation

$$\alpha\left(\frac{d\beta}{dz}-\frac{d\gamma}{dy}\right)+\beta\left(\frac{d\gamma}{dx}-\frac{d\alpha}{dy}\right)+\gamma\left(\frac{d\alpha}{dy}-\frac{d\beta}{dx}\right)=0\quad\text{(IV.)},$$

as the simplest expression of the condition that α, β, γ must satisfy, in order that the distribution which they represent may be complex-lamellar; and we also conclude that if this equation be satisfied the distribution must be complex-lamellar, unless each term of the first number vanishes by equations (III.) being satisfied, in which case the distribution is, as we have seen, lamellar.

76. The resultant force at any point external to a lamellarly-magnetized magnet will, according to § 73 (Cors. 2 and 4.), depend solely upon the edges of the shells into which it may be divided by surfaces perpendicular to the lines of magnetization (or the bands into which those surfaces cut the bounding surface), and not at all on the forms of these shells, within the bounding surface, nor upon any closed shells of which part of the magnet may consist; and the resultant force at any internal point may (§ 73. Cors. 2, 4, and 7,) be obtained by compounding a force depending solely on those edges, with a force in the direction contrary to that of the magnetization of the substance at the point, and equal to the product of 4π into the intensity of the magnetization. For either an external or an internal point, the resultant force may be expressed by means of a potential, according to § 49; and the value of this potential may be obtained by means of the theorems of § 73, in the following manner.

Let us suppose all the open shells, that is to say all the shells cut by the bounding surface of the given magnet, to be removed, and an imaginary series of shells having the same edges, and the same magnetic strengths, and coinciding with the bounding surface, substituted for them; and, for the sake of definiteness, let us suppose each of these shells to have its north polar side outwards, and to occupy a part of the surface for which the value of φ is greater than at its edge. The whole surface will thus be occupied by a series of superimposed magnetic shells, constituting a complex magnetic shell which will produce a potential at any external point the same as that due to the whole of the given magnet; and it will produce a potential at any internal point, which, together with the potential due to the closed shells which

surround it, if there are any, and (§ 73, Cor. 2.) together with the product of 4π into the sum of the strengths of any open shells which have it between them and their superficial substitutes, will be the potential due to the whole of the given magnet at this point.

Now if $d\varphi$ denote the difference between the values of φ at two consecutive surfaces of the series, by which we may conceive the whole magnet to be divided into shells, it follows, from the investigation of § 75, that the magnetic strength of the shell is equal to $d\varphi$. Hence, if A denote the least value of φ at any part of the bounding surface, and φ be supposed to correspond to a point in the surface, the strength of the complex magnetic shell, found by adding the strengths of all the shells of the imaginary series superimposed at this point, will be $\varphi - A$; and if P be an internal point, and the value of φ at it be denoted by (φ), the sum of the strengths of all the shells between that which passes through P and that which corresponds to A, will be $(\varphi) - A$, from which it may be demonstrated*, that, whether (φ) be $>$ or $<A$, and whatever be the nature of the shells, whether all open or some open and some closed, the quantity to be added to the potential due to the imaginary complex shell coinciding with the surface of the magnet to find the actual potential at P, is $4\pi\{(\varphi) - A\}$. Now, from what we have seen above, it follows that the potential at any point P, due to an element, dS, of this complex shell is $\frac{\varphi \cdot \cos\theta dS}{\Delta^2}$, if θ denote the angle which an external normal, or a normal through the north polar side of dS, makes with a line drawn from dS to P, and Δ the length of this line. Hence the total potential at P, due to the whole complex shell, is equal to

$$\iint \frac{\{\varphi + A\}\cos\theta dS}{\Delta^2},$$

in which the integration includes the whole bounding surface of the magnet. Hence, if V denote the potential at P, we have the following expression, according as P is external or internal,—

$$V = \iint \frac{\{\varphi - A\}\cos\theta dS}{\Delta^2},$$

or

$$V = \iint \frac{\{\varphi - A\}\cos\theta dS}{\Delta^2} + 4\pi\{(\varphi) - A\}.$$

These expressions may be simplified if we remark that, for any external point,

$$\iint \frac{\cos\theta dS}{\Delta^2} = 0,$$

and that, for any internal point,

$$\iint \frac{\cos\theta dS}{\Delta^2} = -4\pi$$

(since θ is the angle between the line Δ and the *external* normal through dS). We

* See second foot-note on § 48 above, and Cors. 2, 3, § 76, below.

thus obtain, for an external point,

$$V=\iint \frac{\phi \cdot \cos\theta dS}{\Delta^2};$$

and for an internal point,

$$V=\iint \frac{\phi \cdot \cos\theta dS}{\Delta^2}+4\pi(\phi),$$

. . . . . (V.)

Cor. 1.—The potentials at two points infinitely near one another, even if one be in the magnetized substance and the other be external, differ infinitely little; for the value of

$$\iint \frac{\phi \cdot \cos\theta dS}{\Delta^2},$$

at a point infinitely near the surface and within it, is found by adding $-4\pi(\phi)$ to the value of the same expression at an external point infinitely near the former.

Cor. 2.—If the value of

$$\iint \frac{\phi \cdot \cos\theta dS}{\Delta^2}$$

be denoted by $-Q$ for any internal point, x, y, z; and if $(\alpha), (\beta), (\gamma)$ denote the components of the intensity of magnetization, and X, Y, Z the components of the resultant magnetic force at this point, (that is, according to the definition in the second footnote on § 48, the force at a point in an infinitely small crevass tangential to the lines of magnetization at x, y, z) we have

$$\left.\begin{aligned} X&=-\frac{dV}{dx}=\frac{dQ}{dx}-4\pi(\alpha)\\ Y&=-\frac{dV}{dy}=\frac{dQ}{dy}-4\pi(\beta)\\ Z&=-\frac{dV}{dz}=\frac{dQ}{dz}-4\pi(\gamma)\end{aligned}\right\} \quad . . . . . \text{(VI.)}$$

The resultant of the partial components, $-4\pi(\alpha)$, $-4\pi(\beta)$, $-4\pi(\gamma)$, is a force equal to $4\pi(i)$ acting in a direction contrary to that of magnetization, and this, compounded with the resultant of

$$\frac{dQ}{dx}, \frac{dQ}{dy}, \frac{dQ}{dz},$$

which depends solely on the edges of the shells, gives the total resultant force at the internal point. We thus see precisely how the statements made at the commencement of § 76. are fulfilled.

Cor. 3. It is obvious, by the preceding investigation, that

$$\frac{dQ}{dx}, \frac{dQ}{dy}, \frac{dQ}{dz}$$

are the components of the force at a point in an infinitely small crevass perpendicular to the lines of magnetization at x, y, z.

77. An analytical demonstration of these expressions may be obtained by a partial

integration of the general expression for the potential in the case of a lamellar distribution, in the following manner:—

In equation (5) of § 55, which, as was remarked in the foot-note, expresses the potential for any point, whether internal or external, let $\frac{d\varphi}{dx}$, $\frac{d\varphi}{dy}$, and $\frac{d\varphi}{dz}$ be substituted in place of *il*, *im*, and *in* respectively; and, for the sake of brevity, let

$$\{(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2\}^{\frac{1}{2}}$$

be denoted by Δ: then observing that $\frac{\xi-x}{\Delta^3}=\frac{d\frac{1}{\Delta}}{dx}$, and so for the similar terms; we have

$$V=\iiint\left(\frac{d\varphi}{dx}\frac{d\frac{1}{\Delta}}{dx}+\frac{d\varphi}{dy}\frac{d\frac{1}{\Delta}}{dy}+\frac{d\varphi}{dz}\frac{d\frac{1}{\Delta}}{dz}\right)dxdydz. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

Dividing the second member into three terms, integrating the first by parts commencing with the factor $\frac{d\varphi}{dx}\,dx$, and so for the other terms; we obtain

$$V=\left[\iint\varphi\left(\frac{d\frac{1}{\Delta}}{dx}dydz+\frac{d\frac{1}{\Delta}}{dy}dzdx+\frac{d\frac{1}{\Delta}}{dz}dxdy\right)\right]-\iiint\varphi\left(\frac{d^2\frac{1}{\Delta}}{dx^2}+\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right)dxdydz, \quad . \quad . \quad (b)$$

where the brackets which inclose the double integral denote that it has reference to the surface of the body. Now, for any set of values of x, y, z, for which $\frac{1}{\Delta}$ is finite, we have, as is well known,

$$\frac{d^2\frac{1}{\Delta}}{dx^2}+\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}=0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

and consequently, if the point ξ, η, ζ is not in the space included by the triple integral in the expression for V, each element of this integral, and therefore also the whole, vanishes. In the contrary case, the simultaneous values $x=\xi$, $y=\eta$, and $z=\zeta$ will be included in the limits of integration, and, as these values make $\frac{1}{\Delta}$ infinitely great, the equation (*c*) will fail for one element of the integral, although it still holds for all elements corresponding to points at a finite distance from (ξ, η, ζ). Hence, if (φ) denote the value assumed by the function φ at this point, we have

$$\iiint\varphi\left(\frac{d^2\frac{1}{\Delta}}{dx^2}+\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right)dxdydz=(\varphi)\iiint\left(\frac{d^2\frac{1}{\Delta}}{dx^2}+\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right)dxdydz,$$

where the limits of integration may correspond to any surface whatever which completely surrounds the point (ξ, η, ζ). Now it is easily proved (as is well known) that the value of

$$\iiint\left(\frac{d^2\frac{1}{\Delta}}{dx^2}+\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right)dxdydz$$

is -4π, when (ξ, η, ζ) is included in the limits of integration; and therefore the value of the triple integral, in the expression for V, is $-4\pi(\varphi)$. Hence, according as the point (ξ, η, ζ) is external or internal with reference to the magnet, the potential at it is given by the expressions

$$\left.\begin{aligned} &(1.)\quad V=\Big[\iint\varphi.\left(\frac{d\frac{1}{\Delta}}{dx}dydz+\frac{d\frac{1}{\Delta}}{dy}dzdx+\frac{d\frac{1}{\Delta}}{dz}dxdy\right)\Big] \\ \text{or}\quad &(2.)^{*}\ V=\Big[\iint\varphi.\left(\frac{d\frac{1}{\Delta}}{dx}dydz+\frac{d\frac{1}{\Delta}}{dy}dzdx+\frac{d\frac{1}{\Delta}}{dz}dxdy\right)\Big]+4\pi(\varphi)\end{aligned}\right\}\quad\ldots\ldots\quad(\text{VII.})$$

These agree with the expressions obtained above in § 76; the same double integral with reference to the surface being here expressed symmetrically by means of rectangular coordinates.

78. The value of φ at any point in the surface of the magnet, which, as appears from the preceding investigations, is all that is necessary for determining the potential due to a lamellar magnet at any point not contained in the magnetized substance, may, according to well-known principles, be determined by integration, if the tangential component of the magnetization at every point of the magnet infinitely near its surface be given. It appears therefore that, if it be known that a magnet is lamellarly magnetized throughout its interior, it is sufficient to have given the tangential component of its magnetization at every point infinitely near the surface or to have enough of data for determining it, without any further specification regarding the interior distribution than that it is lamellar, to enable us to determine completely its external magnetic action. This conclusion is analogous to a conclusion which may be drawn, for the case of a solenoidal distribution, from the expression obtained in § 51, for the potential of a magnet of any kind. For, from this expression, we have, according to § 74, the following in the case of a solenoidal distribution:—

$$V=\Big[\iint\frac{(l\alpha+m\beta+n\gamma)dS}{\Delta}\Big]\quad\ldots\ldots\quad(\text{VIII.});$$

from which we conclude, that without farther data regarding the interior distribution than that it is solenoidal, it is sufficient to have given the normal component of the magnetization at every point infinitely near the surface to enable us to determine the external magnetic action. Yet, although analogous conclusions are thus drawn from these two formulæ, the formulæ themselves are not analogous, as the former (that of § 51) is applicable to all distributions, whether solenoidal or not, and shows precisely how the resultant magnetic action will in general depend on the interior distribution besides the normal magnetization near the surface, according to the deviation from

* It may be proved that the force derived from a potential having the same expression (VII.) (1.) as for external points, is, for any internal point, the force at a point within an infinitely small crevass perpendicular to the lines of magnetization; as it is easily shown that the differential coefficients of $4\pi(\varphi)$ are the rectangular components of the force at such a point due to the free contrary polarities on the two sides of the crevass.

being solenoidal which it presents; while the formulæ of § 76. merely expresses a fact with reference to lamellar distributions, and being only applicable to lamellar distributions, do not indicate the effect of a deviation from being lamellar, in a distribution of a general form. Certain considerations regarding the comparison between common magnets and electro-magnets, suggested by AMPÈRE's theorem that the magnetic action of a closed galvanic circuit is the same as that of a "magnetic shell" (as defined in § 67.) of any form having its edge coincident with the circuit, led me to a synthetical investigation of a distribution of galvanism through the interior and at the surface of a magnet magnetized in any arbitrary manner, from which I deduced formulæ, for the resultant force at any external or internal point, giving the desired indication regarding effect of a deviation from being lamellar, on expressions which, for lamellar distributions, depend solely on the tangential component of magnetization at points infinitely near the surface. These galvanic elements throughout the body, from the action of which the resultant force at any external point is compounded, produce effects which are not separately expressible by means of a potential, and therefore, although of course when the three components X, Y, Z of the total resultant force at any point (x, y, z) have been obtained, they will be found to be such that $Xdx+Ydy+Zdz$ is a complete differential, the separate infinitely small elements of which these forces are compounded by integration with reference to the elements of the magnet, do not separately satisfy such a condition. Hence the investigation does not lead to an expression for the potential; but by means of it the following expressions for the three components of the force at any external point, or on a point within any infinitely small crevass perpendicular to the lines of magnetization, have been obtained*:—

$$\left.\begin{aligned}
X&=\iiint dxdydz\left\{\frac{\eta-y}{\Delta^3}\left(\frac{d\alpha}{dy}-\frac{d\beta}{dx}\right)-\frac{\zeta-z}{\Delta^3}\left(\frac{d\gamma}{dx}-\frac{d\alpha}{dz}\right)\right\}-\left[\iint\left\{\frac{\eta-y}{\Delta^3}(m\alpha-l\beta)-\frac{\zeta-z}{\Delta^3}(l\gamma-n\alpha)\right\}dS\right]\\
Y&=\iiint dxdydz\left\{\frac{\zeta-z}{\Delta^3}\left(\frac{d\beta}{dz}-\frac{d\gamma}{dy}\right)-\frac{\xi-x}{\Delta^3}\left(\frac{d\alpha}{dy}-\frac{d\beta}{dx}\right)\right\}-\left[\iint\left\{\frac{\zeta-z}{\Delta^3}(n\beta-m\gamma)-\frac{\xi-x}{\Delta^3}(m\alpha-l\beta)\right\}dS\right]\\
Z&=\iiint dxdydz\left\{\frac{\xi-x}{\Delta^3}\left(\frac{d\gamma}{dx}-\frac{d\alpha}{dz}\right)-\frac{\eta-y}{\Delta^3}\left(\frac{d\beta}{dz}-\frac{d\gamma}{dy}\right)\right\}-\left[\iint\left\{\frac{\xi-x}{\Delta^3}(l\gamma-n\alpha)-\frac{\eta-y}{\Delta^3}(n\beta-m\gamma)\right\}dS\right]
\end{aligned}\right\}\text{(IX.)}$$

The investigation by which I originally obtained these expressions is, with reference to galvanism, precisely analogous to the investigation in § 42. with reference to imaginary magnetic matter. It cannot be given without explanations regarding the elements of electro-magnetism which would exceed the limits of the present communication; but when I had once discovered the formulæ I had no difficulty in working out the subjoined analytical demonstration of them for the case of an external point,

* The expression $Xdx+Ydy+Zdz$ will not be a complete differential for internal points, unless the distribution of magnetism be lamellar, since, for any internal point, X, Y, Z differ from the rectangular components of the resultant force, as defined in § 48, by the quantities $4\pi\alpha$, $4\pi\beta$, $4\pi\gamma$, respectively, and since (§ 52) the resultant force, for all points, whether internal or external, is derivable from a potential.

which is precisely analogous to Poisson's original investigation (shown in § 56. of this paper) of the formula of § 51.

79. Equations (3) and (4) of §§ 51. and 52, lead to expressions for the components of the resultant force at any point in the neighbourhood of a magnet. Taking only one of them, (since the three expressions are symmetrical) that for X for instance, we have

$$X=-\frac{d}{d\xi}\iiint dxdydz\left\{\alpha\frac{d\frac{1}{\Delta}}{dx}+\beta\frac{d\frac{1}{\Delta}}{dy}+\gamma\frac{d\frac{1}{\Delta}}{dz}\right\}.$$

Now if the factor of $dxdydz$ in the second member of this equation be differentiated with reference to ξ, an expression is obtained which does not become infinitely great for any values of x, y, z included within the limits of integration, since the point (ξ, η, ζ) is considered to be external in the present investigation. Hence the differentiation with reference to ξ may be performed under the integral sign; and, since

$$\frac{d\frac{1}{\Delta}}{d\xi}=-\frac{d\frac{1}{\Delta}}{dx},$$

we thus obtain

$$X=\iiint dxdydz\left\{\alpha\frac{d^2\frac{1}{\Delta}}{dx^2}+\beta\frac{d^2\frac{1}{\Delta}}{dy^2}+\gamma\frac{d^2\frac{1}{\Delta}}{dz^2}\right\}*.$$

Now, for all points included within the limits of integration, we have, from Laplace's well-known equation,

$$\frac{d^2\frac{1}{\Delta}}{dx^2}=-\left(\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right),$$

and therefore

$$X=\iiint dxdydz\left\{-\alpha\left(\frac{d^2\frac{1}{\Delta}}{dy^2}+\frac{d^2\frac{1}{\Delta}}{dz^2}\right)+\beta\frac{d^2\frac{1}{\Delta}}{dxdy}+\gamma\frac{d^2\frac{1}{\Delta}}{dxdz}\right\}.$$

* If the point (ξ, η, ζ) be either within the magnet, or infinitely near it, the factor of $dxdydz$ in this integral is infinitely great for values of (x, y, z) included within the limits of integration; and it may be demonstrated that the value of a part of the integral corresponding to any infinitely small portion of the magnet infinitely near the point (ξ, η, ζ) is in general finite, and that it depends on the form of this portion, on its position with reference to the line of magnetization through (ξ, η, ζ), and on the proportions of the distances of its different parts from this point. It follows that if the point ξ, η, ζ be internal, and if a portion of the magnet round it be omitted from the integral, the value of the integral will be affected by the form of the omitted portion, however small its dimensions may be, and consequently the complete integral has no determinate value if the point (ξ, η, ζ) be internal. Hence, although as we have seen above (§§ 51,*51.),

$$-\frac{d}{d\xi}\iiint dxdydz\left\{\alpha\frac{d\frac{1}{\Delta}}{dx}+\beta\frac{d\frac{1}{\Delta}}{dy}+\gamma\frac{d\frac{1}{\Delta}}{dz}\right\}$$

has in all cases a determinate value, which, by the definition (§ 48.), is called the component parallel to OX of the resultant force at (ξ, η, ζ), the expression

$$-\iiint dxdydz\frac{d}{d\xi}\left\{\alpha\frac{d\frac{1}{\Delta}}{dx}+\beta\frac{d\frac{1}{\Delta}}{dy}+\gamma\frac{d\frac{1}{\Delta}}{dz}\right\}$$

has no meaning when (ξ, η, ζ) is in the substance of the magnet.

Dividing the second member into four terms, and applying an obvious process of integration by parts, we deduce

$$X=\Big[\iint\Big\{-\alpha\frac{d\frac{1}{\Delta}}{dy}dxdz-\alpha\frac{d\frac{1}{\Delta}}{dz}dxdy+\beta\frac{d\frac{1}{\Delta}}{dy}dydz+\gamma\frac{d\frac{1}{\Delta}}{dz}dydz\Big\}$$

$$+\iiint dxdydz\Big\{\frac{d\alpha}{dy}\frac{d\frac{1}{\Delta}}{dy}+\frac{d\alpha}{dz}\frac{d\frac{1}{\Delta}}{dz}-\frac{d\beta}{dx}\frac{d\frac{1}{\Delta}}{dy}-\frac{d\gamma}{dz}\frac{d\frac{1}{\Delta}}{dz}\Big\}\Big].$$

Modifying the double integral by assuming, in its different terms,

$$dydz=ldS\,;\quad dzdx=mdS\,;\quad dxdy=ndS,$$

and altering the order of all the terms, we obtain

$$X=\iiint dxdydz\Big\{\frac{d\frac{1}{\Delta}}{dy}\Big(\frac{d\alpha}{dy}-\frac{d\beta}{dx}\Big)-\frac{d\frac{1}{\Delta}}{dz}\Big(\frac{d\gamma}{dx}-\frac{d\alpha}{dz}\Big)\Big\}-\Big[\iint\Big\{\frac{d\frac{1}{\Delta}}{dy}(m\alpha-l\beta)-\frac{d\frac{1}{\Delta}}{dz}(l\gamma-n\alpha)\Big\}dS\Big].$$

This expression, when the indicated differentiations are actually performed upon $\frac{1}{\Delta}$, becomes identical with the expression for X at the end of § 78, and the formulæ which it was required to prove are therefore established.

80. The triple integrals in these expressions vanish in the case of a lamellar distribution, in virtue of the equations (III.) of §§ 75; and we have simply

$$\left.\begin{aligned}X&=-\Big[\iint\Big\{\frac{d\frac{1}{\Delta}}{dy}(m\alpha-l\beta)-\frac{d\frac{1}{\Delta}}{dz}(l\gamma-n\alpha)\Big\}dS\Big]\\ Y&=-\Big[\iint\Big\{\frac{d\frac{1}{\Delta}}{dz}(n\beta-m\gamma)-\frac{d\frac{1}{\Delta}}{dx}(m\alpha-l\beta)\Big\}dS\Big]\\ Z&=-\Big[\iint\Big\{\frac{d\frac{1}{\Delta}}{dx}(l\gamma-n\alpha)-\frac{d\frac{1}{\Delta}}{dy}(n\beta-m\gamma)\Big\}dS\Big]\end{aligned}\right\}\quad\ldots\ldots\ (X.).$$

To interpret these expressions, let us assume, for brevity,

$$U=n\beta-m\gamma\,;\ V=l\gamma-n\alpha\,;\ W=m\alpha-l\beta\quad\ldots\ldots\ (XI.).$$

From these we deduce

$$\left.\begin{aligned}mW-nV&=\alpha-l\,(l\alpha+m\beta+n\gamma)=\alpha_1\\ nU-lW&=\beta-m(l\alpha+m\beta+n\gamma)=\beta_1\\ lV-mU&=\gamma-n\,(l\alpha+m\beta+n\gamma)=\gamma_1\end{aligned}\right\}\quad\ldots\ldots\ (XII.);$$

where α_1, β_1, γ_1 denote the rectangular components of the tangential component of the magnetization at a point infinitely near the surface. Conversely, from these equations we deduce

$$U=n\beta_1-m\gamma_1\,;\ V=l\gamma_1-n\alpha_1\,;\ W=m\alpha_1-l\beta_1\quad\ldots\ldots\ (XIII.).$$

Now the direct data required for obtaining the values of X, Y, and Z, by means of formulæ (X.), are simply the values of U, V, W at all points of its surface. Equa-

tions (XII.) show that with these data the values of $\alpha_1, \beta_1, \gamma_1$ may be calculated; and again, equations show conversely that if $\alpha_1, \beta_1, \gamma_1$ be given the required data for the problem may be immediately deduced. We infer that the necessary and sufficient data for determining the resultant force of a lamellar magnet, at any external point, by means of formulæ (X.), are equivalent to a specification of the direction and magnitude of the tangential component of the intensity of magnetization at every point infinitely near the surface of the magnet; and we conclude, as we did in § 78 from a very different process of reasoning, that besides these data, nothing but that it is lamellar throughout need be known of the interior distribution.

81. The close analogy which exists between solenoidal and lamellar distributions of magnetism having led me to the new formulæ which have just been given, it occurred to me that a formula (or formulæ, if it were necessary here to separate the cases of internal and external points,) for solenoidal distributions analogous to the formulæ (VII.) of §§ 77 for lamellar distributions might be discovered. Taking an analytical view of the problem (the synthetical view, although itself much more obvious, not showing any very obvious way of arriving at a formula of the desired kind), I observed that the formula $\iint \frac{\varphi \cdot \cos\theta dS}{\Delta^2}$ is deduced from the general expression for the potential, by a partial integration performed upon factors involving α, β, γ, and depending on the integrability of the function $\alpha dx+\beta dy+\gamma dz$, ensured by the equations

$$\frac{d\beta}{dz}-\frac{d\gamma}{dy}=0, \quad \frac{d\gamma}{dx}-\frac{d\alpha}{dz}=0, \quad \frac{d\alpha}{dy}-\frac{d\beta}{dx}=0,$$

for a lamellar distribution; and I endeavoured to find a corresponding mode of treatment for solenoidal distributions, to consist of a partial integration, commencing still with factors involving α, β, γ, but depending now upon the single equation

$$\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (a),$$

instead of three equations required in the former process. After some fruitless attempts to connect this equation with the integrability of some function of two independent variables, I fell upon the following investigation, which exactly answered my expectations.

82. In virtue of the preceding equation (a), we may assume

$$\alpha=\frac{d\mathrm{H}}{dy}-\frac{d\mathrm{G}}{dz}, \quad \beta=\frac{d\mathrm{F}}{dz}-\frac{d\mathrm{H}}{dx}, \quad \gamma=\frac{d\mathrm{G}}{dx}-\frac{d\mathrm{F}}{dy} \quad \ldots\ldots\ldots \quad (\mathrm{XIV.}),$$

where F, G, H are three functions to a certain extent arbitrary, which, as I have since found, have for their most general expressions

$$\left.\begin{aligned} \mathrm{F}&=\iint dydz\left(\frac{d\beta}{dy}-\frac{d\gamma}{dz}\right)+\frac{d\psi}{dx} \\ \mathrm{G}&=\iint dzdx\left(\frac{d\gamma}{dz}-\frac{d\alpha}{dx}\right)+\frac{d\psi}{dy} \\ \mathrm{H}&=\iint dxdy\left(\frac{d\alpha}{dx}-\frac{d\beta}{dy}\right)+\frac{d\psi}{dz} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (\mathrm{XV.})$$

where ψ denotes an absolutely arbitrary function; and the indicated integrations are indefinite, with the arbitraries which they introduce subject to the equations (XIV.).

The demonstration of these equations follows immediately from the results obtained by differentiating the three equations (XIV.) with reference to x, y and z respectively. The simplest final forms for F, G and H are the following, which are deduced from the preceding by integration:—

$$\left.\begin{aligned} \mathrm{F} &= \int(\beta dz - \gamma dy) + \frac{d\psi}{dx} \\ \mathrm{G} &= \int(\gamma dx - \alpha dz) + \frac{d\psi}{dy} \\ \mathrm{H} &= \int(\alpha dy - \beta dx) + \frac{d\psi}{dz} \end{aligned}\right\} \quad \text{(XVI.)}$$

Making substitutions according to the formulæ (XIV.) for α, β, γ in the general expression for the potential, we have

$$\mathrm{V} = \iiint dx dy dz \left\{ \left(\frac{d\mathrm{H}}{dy} - \frac{d\mathrm{G}}{dz}\right)\frac{d\frac{1}{\Delta}}{dx} + \left(\frac{d\mathrm{F}}{dz} - \frac{d\mathrm{H}}{dx}\right)\frac{d\frac{1}{\Delta}}{dy} + \left(\frac{d\mathrm{G}}{dx} - \frac{d\mathrm{F}}{dy}\right)\frac{d\frac{1}{\Delta}}{dz} \right\}.$$

Dividing the second member into six terms, and integrating each by parts, commencing upon the factors such as $\frac{d\mathrm{H}}{dy}\,dy$, we obtain an expression, with a triple integral involving six terms which destroy one another two and two because of properties such as

$$\frac{d}{dy}\frac{d\frac{1}{\Delta}}{dx} = \frac{d}{dx}\frac{d\frac{1}{\Delta}}{dy};$$

and besides, a double integral, which may be reduced in the usual manner to a form involving $d\mathrm{S}$, an element of the surface. We thus obtain, finally,

$$\mathrm{V} = \left[\iint \left\{ (m\mathrm{H} - n\mathrm{G})\frac{d\frac{1}{\Delta}}{dx} + (n\mathrm{F} - l\mathrm{H})\frac{d\frac{1}{\Delta}}{dy} + (l\mathrm{G} - m\mathrm{F})\frac{d\frac{1}{\Delta}}{dz} \right\} d\mathrm{S} \right] \quad \text{(XVII.)}$$

83. The second member of this equation expresses the potential of a certain distribution of magnetism in an infinitely thin sheet coinciding with the surface of the body; the total magnetic moment of the magnetism in the area $d\mathrm{S}$ being

$$\{(m\mathrm{H} - n\mathrm{G})^2 + (n\mathrm{F} - l\mathrm{H})^2 + (l\mathrm{G} - m\mathrm{F})^2\}^{\frac{1}{2}} d\mathrm{S},$$

and its direction cosines proportional to

$$m\mathrm{H} - n\mathrm{G}, \quad n\mathrm{F} - l\mathrm{H}, \quad l\mathrm{G} - m\mathrm{F}.$$

Now we have identically,

$$l(m\mathrm{H} - n\mathrm{G}) + m(n\mathrm{F} - l\mathrm{H}) + n(l\mathrm{G} - m\mathrm{F}) = 0;$$

and hence the direction of this imaginary magnetization at every point of the surface is perpendicular to the normal. It follows that we have found a distribution of tangential magnetism in an infinitely thin sheet coinciding with the bounding surface

which produces the same potential at any point, internal or external, as the given solenoidal magnet.

84. The same general conclusion may be arrived at synthetically in a very obvious manner, by taking into account the property of a solenoid stated in § 71, according to which it appears that any two solenoids of equal strength, with the same ends, produce the same force at any point whether in the magnetized substance of either, or not. For it follows from this, that when a magnet is divisible into solenoids with their ends on its surface, by joining the two ends of each solenoid by any arbitrary curve on this surface and laying a solenoid of equal strength along this curve, we obtain a series of solenoids, constituting by their superposition, a tangential distribution of magnetism in an infinitely thin sheet coinciding with the bounding surface, which produces the same resultant force at any internal or external point as the given magnet. It is not, however, easy to deduce from this synthesis, a formula involving the requisite arbitrary functions to express a superficial distribution satisfying the existing conditions in the most general manner. The analytical investigation given above, supplies, in reality, a complete solution of this problem.

It may be remarked that the sole condition which F, G and H, considered as functions of the coordinates, x, y, z, of some point in the surface of the magnet, and therefore functions of two independent variables, must satisfy in order that (XVII.) may express correctly the potential at any point—

$$l\left(\frac{dH}{dy}-\frac{dG}{dz}\right)+m\left(\frac{dF}{dz}-\frac{dH}{dx}\right)+n\left(\frac{dG}{dx}-\frac{dF}{dy}\right)=l\alpha+m\beta+n\gamma, \quad . \quad . \quad \text{(XVIII.)},$$

x, y and z of course being supposed to satisfy the equation to the surface; and it may be proved, by a demonstration independent of the investigation which has been given, that the second member of (XVII.) has the same value for any functions F, G, H whatever, which are subject to this relation.

END OF CHAPTER V.

XII. *Magnetic Survey of the Eastern Archipelago. By Captain* C. M. Elliot, *of the Madras Engineers. Communicated by Lieut.-Col.* Sabine, *V.P. Treas. R.S. &c.*

Received January 15,—Read January 16, 1851.

In accordance with instructions received from the Honourable the Court of Directors of the East India Company, and at the recommendation of the Royal Society, I commenced, in the month of January 1846, the Magnetic Survey of the Eastern Archipelago.

As, in the prosecution of this work, I was left entirely to my own discretion, I may be permitted to state, that the principal object of the Survey appeared to me to consist in determining the position of certain magnetic lines which were included within the space I had to traverse; such, for instance, as the line of no dip, and of the maximum horizontal component of the force; from these, to determine the line of minimum intensity; and finally, the line of no variation and its direction. The determination of these lines I considered to be the principal object; but in addition, I was anxious to take hourly observations of the elements of the earth's magnetism, in order to ascertain whether the changes of declination and of magnetic intensity were uniformly similar over so large an area. The fixed stations for this latter purpose were sixteen in number, and the time employed at each station varied from a few days to several months. The fixed stations were spread over an area of 28° of latitude and of 45° of longitude, viz. from 16° latitude north to 12° latitude south, and from 80° to 125° longitude east. With reference to the line of no dip, which in this part of the globe coincides very nearly with the line of minimum intensity, I may state, that of the sixteen stations, nine were to the south, three to the north, and four in its immediate vicinity. With reference to geographical position, four were in the islands adjacent to Singapore; one in Borneo; one in the island of Java; two in Sumatra; one in the island of Mindanao; one in Celebes; one at the Cocos or Keeling Islands, which was the most southern station to which I could venture; one at Penang, and one in its immediate vicinity; one at Nicobar, in the bay of Bengal; one at Moulmein, which was my most northern; and, finally, one at Madras, which was my most western station. The Survey is however incomplete, as it would have been desirable to extend it considerably more to the eastward, in order to lay down with greater certainty the continuation, of the line of no dip and of the line of minimum intensity; and likewise I should have wished to proceed more to the northward, to ascertain with greater exactitude, at what distance north of the line of minimum intensity, the magnetic declination changes those periods of extreme easterly and extreme westerly variation, by which it is characterized in the southern magnetic hemisphere.

In January 1846 I started from Singapore, and after visiting some islands in the vici-

nity, which I was enabled to do through the kindness of Colonel Butterworth, C.B., the Governor of the Straits, I proceeded, in May 1846, to Borneo, where I remained some time with my friend Sir James Brooke, K.C.B., and making Sarāwak my head-quarters, I took observations at several of the Dutch settlements on the western coast. From Borneo I proceeded to Java, where I passed ten months, and went on to Sumatra in August 1847; but from severe illness brought on through over-exertion in the magnetic survey of part of that island, I was forced to return to Singapore for medical advice in February 1848. At Singapore I remained for some weeks; during which time I was able to take a considerable number of observations of dip and of horizontal intensity; and early in April 1848 I again left Singapore, and visited successively, Pulo Labooan, Sambooanga in the island of Mindanao, and Keemah in the Celebes. From Keemah I proceeded to the Keeling or Cocos Islands, and from the Cocos returned to Batavia, whence I was on the point of proceeding to the eastward and to New Guinea; when I received instructions which induced me to return to Madras, in consequence of having unfortunately very much exceeded the time allotted to me; and thus an end was put to the Survey, which the liberal patronage of the Court of Directors of the East India Company had enabled me to undertake, and which I had hoped to render complete. I returned to Singapore at the close of the year 1848; and here let me gratefully acknowledge, the kind and hospitable treatment I received everywhere from the Dutch authorities. No restrictions were placed on my movements; I was allowed to proceed wherever I chose, and I rejoice at the opportunity thus afforded me of recording my sense of their uniform liberality; nor can I omit mentioning my obligations to His Excellency Baron Rochussen, the Governor-General of the Dutch Possessions in the East; to His Excellency General Van der Weyck, the Commander-in-Chief in Java, and to Captain Smitz, the Hydrographer, who rendered me very great service in his superintendence of the magnetic observatory during my occasional absence from Batavia.

Quitting Singapore for the last time, I stopped at Penang on my way to Nicobar Island, which I was anxious to visit from its being in the immediate vicinity of the line of no dip and of minimum intensity.

I then visited Moulmein, and from Moulmein proceeded to Madras, which I reached in June 1849, from which time till the month of October I was employed there in taking a complete set of absolute determinations, and of hourly magnetic observations, in which latter duty I received the kind aid of Captain Jacob, the Honourable East India Company's Astronomer. Madras was my last station, and I there concluded the Survey. Having then to reduce and bring into shape an enormous mass of work, it occurred to me that the difficulties I should encounter in publishing in India a system of observation, combining the details of a fixed observatory with those of a magnetic survey, would be very great. I therefore applied for furlough, and came to England for the sole purpose of publishing my observations, after reducing them into as condensed a form as was consistent with perspicuity.

Since my arrival in England I have been in constant communication with Colonel

SABINE, R.A., to whose zealous superintendence and advice I am indebted, on almost every point connected with the reduction of the observations: I have likewise to express my obligations to Dr. LLOYD for his advice and for many acts of kindness; from their joint Report on the Magnetic Isoclinal and Isodynamic Lines in the British Islands, I have laid down, in a manner similar to the method there adopted, the different magnetic lines on the Chart of the Eastern Seas; while to the "Magnetical Instructions for the use of Portable Instruments," drawn up by Captain RIDDELL, R.A., I am indebted for the abstracts and forms in which the different instruments are registered.

I do not therefore pretend to any originality in my plan; and the only merit I lay claim to is, that these observations, taken under many difficulties, were made with the earnest desire to do credit to the Royal Society, who recommended the Survey, and to the East India Company, whose munificence enabled me to undertake it.

The Survey consisting; first, of the observation of the differential changes of magnetic and meteorological phenomena at sixteen stations; secondly, of absolute determinations of dip, intensity, and variation in Java, Sumatra, Borneo and other islands of the Archipelago; thirdly, of magnetic and meteorological observations at sea,—it will perhaps be best to treat of each separately, and I shall therefore commence with the observatories.

The following Table contains the names of the different stations at which observatories were established, commencing with the most northerly. The first column contains the stations; the second and third, the latitudes and longitudes; the fourth and fifth, the materials with which the observatories were constructed; the sixth, the nature of the soil; the seventh, the number of days of observation; the eighth, the year and month; and the ninth, the place of observation.

Station.	Latitude.	Longitude.	Materials with which the Observatories were constructed.		Nature of soil.	No. of days observation.	Year and Month.	Places of observation.
			Roof.	Walls.				
Moulmein ...	16° 26′ 49″ N.	97° 45′ 30″ E.	Double thickness of canvas.	Cotton-cloth ...	Clay	7	April 1849	Near Captain BEADMORE's house.
Madras	13 04 09	80 16 30	Cotton-cloth ...	Cotton-cloth ...	Clay and sand.	34	Aug. and Sept. 1849 .	At the fixed Magnetic Observatory.
Nicobar	9 10 12	92 48 25	Double thickness of canvas.	Cotton-cloth ...	Coral and sand.	5	February 1849.....	Near the sea-shore.
Sambooanga .	6 54 20	122 13 45	Double thickness of canvas.	Canvas.....	Clay and sand.	6	May 1848	Near the sea-shore.
Penang	5 25 36	100 24 30	Double thickness of canvas.	Folds of cotton-cloth.	Clay and sand.	5	January 1849	Near the sea-shore.
Pulo Dinding	4 12 47	100 32 52	Double thickness of canvas.	Folds of cotton-cloth.	Clay.....	3	January 1849	Near the sea-shore.
Sarāwak	1 33 54	110 29 00	Thatched with leaves of Neepa.	Leaves of the Neepa palm.	Clay.....	72	June, July and August 1846.	Near Sir J. BROOKE's house.
Keemah, Celebes.	1 21 55	125 07 59	Canvas.....	Canvas.....	Clay.....	10	June 1848	In the village, not far from the shore.
Pulo Peesang	1 27 53	103 19 15	Canvas.....	Canvas.....	Clay and sand.	5	January 1846	Close to the sea-shore.
Singapore ...	1 18 32	103 56 30	Thatched with leaves of Neepa.	Wood and sun-burnt bricks.	Sand upon blue clay.	30	Nov. and Dec. 1848 .	At the fixed Magnetic Observatory.
Carimon.....	0 59 22	103 27 00	Canvas.....	Canvas.....	Sand	6	January 1846	Close to the sea-shore.
Pulo Booāya .	0 09 09	104 21 00	Canvas.....	Canvas.....	Sand	4	February 1846.....	On the sea-shore.
Padang, Sumātra.	0 58 58 S.	100 31 15	Double thickness of canvas.	Canvas.....	Ferruginous sand.	78	Oct., Nov., Dec., 1847 & and Jan. 1848.	Near the sea-shore.
Batavia	6 09 52	106 58 00	Thatched with leaves of Neepa.	Thick bamboo matting.	Clay.....	199	From Nov. 1846 to July 1847.	In the midst of a vast plain of rice-fields.
Cocos or Keeling Islands.	12 05 38	96 50 30	Double thickness of canvas.	Cocoa-nut leaves	Fragments of coral.	27	August and September 1848.	Close to the sea-shore.

The instruments in use at the observatories were the following:—

No. I. Portable Declination Magnetometer, showing changes of declination or of variation.

No. II. Induction Inclinometer, showing likewise changes of declination.

No. III. Jones' new Declinometer, in use during the latter period of the Survey, showing likewise changes of declination.

Nos. IV. and V. Portable Bifilar Magnetometer with Thermometer, showing changes of horizontal intensity.

Nos. VI. and VII. Barometer and Thermometer; Newman's Standard Barometer was in use during the first part of the Survey; and latterly, a Portable Instrument by Cary.

Nos. VIII. and IX. Dry and Wet-bulb Thermometers.

No. X. Standard Thermometer.

Nos. XI. and XII. Maximum and Minimum Thermometers.

Observatories, Position of the Instruments, &c.

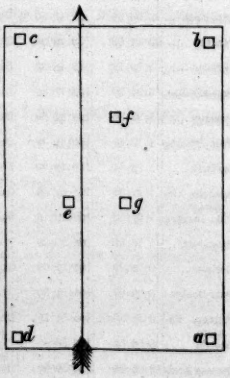
As all the observatories were constructed upon the same principle, it will not be necessary to give the positions and adjustments of the instruments at more than two of the stations; the details of the rest being precisely of a similar nature; for this purpose the position of the instruments, their adjustments and the dimensions of the observatories on Direction Island, Cocos; and at Batavia, are given.

Observatory on Direction Island, Cocos or Keeling Islands.

The observations at the Cocos or Keeling Islands were made on Direction Island, with the usual magnetic and meteorological instruments. The soil on Direction Island consists of a few inches of vegetable soil, and of several feet in depth of fragments of coral. The observatory tent was pitched in the midst of a thick plantation of cocoa-nut trees about 8 feet above the level of low-water mark, and about 50 yards from the sea.

Dimensions of the tent 19 × 13 feet. Tent consisted of a double lining of canvas, and the walls of cocoa-nut leaves.

a. Declinometer No. I.
b. Declinometer No. II.
c. Declinometer No. III.
d. Bifilar and Thermometer.
e. Barometer and Thermometer.
f. Dry and Wet Bulb.
g. Standard Thermometer.

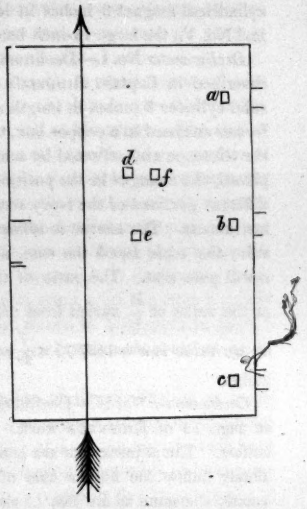


The magnetic instruments were placed at the four corners as remote from one another as the dimensions of the tent would permit. The Standard Thermometer was attached to one of the poles of the tent. The Barometer fixed to a detached post firmly imbedded in the

ground. The Dry and Wet-Bulb Thermometers were placed on a small table, 5 feet above the ground.

Observatory at Batavia.

The dimensions of this building were 42×28 feet, and almost wholly constructed of bamboo; the walls were 12 feet in height, composed of thick bamboo matting, and the roof was thatched with leaves of the Neepa palm. The soil was a very stiff clay, and the spot selected was in the midst of extensive rice-fields.



a. Bifilar Magnetometer, on a pillar constructed of sun-dried bricks, capped by a slab of granite.

b. Declinometer No. II. on a wooden stand.

c. Declinometer No. I. on a pillar of sun-dried bricks.

d. Standard Barometer with its Thermometer.

e. Dry and Wet Bulb.

f. Standard Thermometer.

The Bifilar at the N.E. angle, the scale facing the south; Declinometer No. II. at the point *b*, and Declinometer No. I. at the point *c*, both facing the east, the instruments being about 18 feet apart; the Dry and Wet Bulb on a table at *e*; the Standard Barometer attached to a post firmly imbedded in the earth at *d*; the Standard Thermometer fixed to a post at *f*.

Times of Observation.

Having during the greater part of the Survey but one assistant, I limited the observations to nineteen hours daily, viz. hourly observations from 3 A.M. to 9 P.M. To this arrangement there are exceptions; as at Sarāwak and during the first four months at Batavia, when I had three assistants; and then observations were taken hourly during the twenty-four hours. By astronomical time, therefore, the observations generally commenced at fifteen hours, and terminated at nine hours.

Order in which the Instruments will be noticed.

The instruments will be noticed in the following order:—The Declinometers, the Bifilar, the Dry and Wet-Bulb Thermometers, the Barometer, the Standard Thermometer, and the Maximum and Minimum Thermometers.

Declinometers.

There were never less than two declinometers observed at the same station, and subsequently, when JONES's declinometer was received, all three were put in adjust-

ment and observed. At Pulo Peesang, Carimon, Pulo Booāya, Sarāwak, Batavia, Poolo Bay, Padang and Sambooanga, Nos. I. and II. were employed; at Moulmein, Nos. II. and III.; at Keemah, the Cocos, Pulo Dinding, Penang, Nicobar, and Madras, Nos. I. II. and III.; and at Singapore, in November and December 1848, not only were the three above-mentioned observed, but two in addition, viz. No. IV., a small cylindrical magnet 3 inches in length, in use for deflection in a separate building, and No. V., the large 15-inch bar in the observatory.

Declinometer No. I.—Declinometer No. I. is the Portable Declination Magnetometer described in Captain RIDDELL's work on Magnetic Instruments; the magnet is a solid cylinder 3 inches in length and suspended by a filament of untwisted silk; the former enclosed in a copper box, the latter in a glass tube. A scale being fixed above the telescope and reflected by a mirror attached to the stirrup in which the magnet is placed, the changes in the position of the magnet are shown by the mirror reflecting different portions of the ivory scale, and are read off by the telescope attached to the instrument. The mirror is immediately below the magnet and parallel to its longer axis; the scale faced the east, and increasing readings denote a movement of the north pole east. The ratio of the torsion force to the magnetic directive force, or the value of $\frac{H}{F}$, varied from ·000207 to ·000278. The value of one scale division in arc value is $a' = 3437{\cdot}75 \times \frac{l}{2r} = 1'{\cdot}00$, where $l = \frac{1}{100}$th of an inch = ·01 and $r = 17{\cdot}19$ inches.

Declinometer No. II.—Declinometer No. II. is the Induction Inclinometer described at page 12 of RIDDELL's work. The magnet is of the same length as No. I., but hollow. The adjustments are precisely similar. The mirror is parallel to and immediately below the longer axis of the magnet. The value of one scale division is exactly the same as for No. I., viz. 1′ of arc. The coefficient of torsion varied from ·000139 to ·00025, and is therefore not worth taking into account, except for large angles of deflection.

Declinometer No. III.—Declinometer No. III., or JONES's Declinometer, is precisely similar in principle to the two others; the magnet being a solid cylinder 3 inches in length. The mirror, instead of being parallel to the longer axis of the magnet, is at right angles to it, so that the scale, instead of facing the east, being to the south of the magnet, faced the north. Increasing scale readings denote a movement of the north pole east. The value of one scale division is 1′·0036; the coefficient of torsion ·00031.

Contents of Abstracts of Table A. *referring to the Declinometers.*

In the abstracts of Table A. are given, from page i to page xi inclusive, the oscillation, or more properly the variation of the declination* at the different stations in

* In order to obviate confusion as much as possible, I have substituted in Table A. for hourly variation the word oscillation, which is meant to express the extreme range or swing of the needle from its most western to its most eastern position: the term hourly variation has not been used in Table A., as it might be con-

the Eastern Archipelago; pages ii and iii contain the mean oscillation of the declination, the range extending from the most westerly declination assumed as zero, to the most eastern position of the magnet. As increasing readings denote a movement of the north pole of the magnet eastward, the lowest number will of course be the most western position or zero, the highest number being the most eastern position. As these tables contain the mean oscillation for several months, the oscillations at those stations where observations have been taken for more than one month are given in pages iv to vii inclusive.

In addition to the three Portable Declinometers, No. IV., a small 3-inch cylinder used as the deflected magnet in the determination of the absolute horizontal intensity, and No. V., the 15-inch observatory bar, were observed at Singapore. The oscillations of these two instruments are given at pages iv and v, reduced to minutes of angular space, and the mean results are included in the Table of Declinometer No. III. at pages ii and iii. It occurred to me constantly whilst at the observatory to note, that not only did the large magnet differ from the smaller magnets in its time of changing, but the range or oscillation was not the same; the time of change differed but slightly it is true; but it was not identically the same*. I determined therefore to use on the Survey never less than two magnets; one a solid, the other a hollow cylinder, for the changes of declination; and on my return to Singapore in 1848, I took nearly simultaneous observations of as many declination magnets as could be observed together.

On inspection of the Tables of the mean oscillation of the declination at pages ii and iii, I was struck with the dissimilarity of the times of occurrence of minimum westerly declination at the different survey stations; and as the observations were taken at all seasons of the year, it appeared to be exceedingly desirable to have some fixed observatory to refer to, to ascertain what changes might be due to geographical position and what changes to the time of the year. I have, therefore, at pages viii, ix, x and xi, given the mean hourly oscillation of the magnetic declination at the Singapore Observatory, for each season being the mean of three years; the mean of each of the months; and finally, the mean of each of the three years, showing the

founded with the angle α, or the angle which the magnetic meridian forms with the true meridian, and which is usually called the variation of the needle; but to prevent mistakes, for the angle α, the term magnetic declination has been substituted, in accordance with the method now generally adopted.

* I attributed at the time this difference of range, and the turning points not being exactly simultaneous, to the method of suspension by filaments of silk, and the constant change to which the force of torsion was liable from the hygrometric properties of the silk. The large observatory 15-inch bar was suspended by eighteen fibres of untwisted silk; and when a fresh adjustment became necessary from the threads breaking, a brass bar was swung, in order to take the torsion out of the new suspension thread: after getting the brass bar accurately into the magnetic meridian, it would remain in the same position for several hours; but, if adjusted during the day, it would be found, after the lapse of a night, forming some angle with the magnetic meridian; thus, from some cause, hygrometric or otherwise, the plane of detorsion was no longer in the same position in which it had previously been in adjustment.

remarkable similarity of one year with another. As the sole object in giving these Singapore tables, was to determine the times of extreme easterly and westerly declination, in the southern magnetic hemisphere near the line of minimum intensity, the results of the Singapore Observatory magnet are not in this instance given in minutes of arc, but in scale divisions; one scale division being equal to $40''{\cdot}7$ of arc.

Table A.—Pages xii to xlvii contain the results of the declinometers at the sixteen stations in the Archipelago. The stations are given proceeding from the most northern to the most southern: the observations themselves are omitted. At the top of every double page is printed the name of the station, with its latitude and longitude; the mean astronomical time at the station; and the value of one scale division in minutes of arc, multiplied by the coefficient of torsion or $1+\frac{H}{F}$; the value of which is so trifling as not to affect the small diurnal changes of the magnet; and the zero of the month, which is the scale division of the magnet at that hour at which the absolute determination of the magnetic declination was made, usually at 9 A.M. The results of each instrument are contained in five lines; the first, the sums of the scale readings; the second, the means; the third, the diurnal changes, from the mean of the month*; the fourth, the range or oscillation of the needle, from its minimum or most western position; and the fifth, the diurnal declination.

Curves.

The curves of the declinometer are given in Plates IV., V. and VI. Part 1 of Plate IV. contains the curves of the declinometer at those stations where observations were made during the spring and summer; Part 2 of Plate IV. and Part 1 of Plate V. the winter curves; Part 2 of Plate V. the equinoctial curves. The two Plates are drawn to a scale of $1'$ of arc to 0·35 of an inch, and Plate VI. contains the Singapore curves, which are drawn on a scale of $0'{\cdot}68$ of arc (the value of one scale division) to 0·35 of an inch. In the three Plates the zero line is the line of the magnet's most westerly position. The curve rising denotes a movement of the north pole of the magnet eastward. The curves themselves show, by the description of dotting, to which season they belong.

As the station curves have to be compared separately with Singapore, it will be preferable to consider first the principal changes of the Singapore curves shown in Plate VI. In Part 1 of Plate VI., which gives the mean curve of each month for three years, it appears that the minimum or westerly declination occurs at Singapore in December at 19 hours; in January at 20; in February at 21; in March (equinoctial month) a slight retrogression to 20; in April at 21; in May at 23; in June at 21;

* The mean of the month being the mean of the whole number of observations; where there are but nineteen hours of observation, and these principally in the daytime, the mean of these for a mean temperature would unquestionably be too high; five of the hours of the night being omitted, the mean of the nineteen observed hours would be greater than the true mean; but this is not the case with the magnetic declination, the range being exceedingly small at night, and usually close upon the mean position of the needle.

in July and August at 23; in September at 22; in October at 21; and in November at 20 hours. If the seasons are projected in curves as in Part 2 of Plate VI., we find in winter the minimum at 20 hours; in spring at 21 hours; in summer at 23 hours; and in autumn back to 21 hours; agreeing in this with the spring curve, but differing very materially as regards the progression of the needle eastward in the afternoon; autumn and winter agreeing in this latter respect, and also spring and summer. The oscillation of the curve exhibits a much greater range during the winter months*; the autumn curve is next in extent of range and in the afternoon preserves a certain degree of parallelism with the winter curve; and both these curves have the afternoon maximum more decidedly expressed, and have also a higher maximum than in the morning. The reverse of this is the case with the spring and summer curves.

The mean curves of the three years exhibit a wonderful uniformity and almost total resemblance. There are two most decided maxima at 18 and at 3 or 4 hours, and one minimum at 21. There are besides two other minima at 10 and at 17 hours more faintly expressed. If we turn to the seasons, we find only one strongly defined maximum and minimum or a single progression in winter; in spring two strongly expressed maxima and one minimum; in summer and in autumn two maxima and two minima; and as these maxima and minima occur at different periods, the mean annual curve thus blends the leading characteristics of all, and presents accordingly a double, if not a triple progression.

On an inspection of the Plates, and on comparing them with the Singapore curves, we find that in Part 1 of Plate IV. the Moulmein April curve resembles no single curve in any one month at Singapore. The curve is that described by Declinometer No. III.; there are two minima at 17 and 1, and two maxima at 20 and 5 hours. Moulmein is about 8° north of the line of minimum intensity.

The next two in Part 1 of Plate IV. are the Sambooanga May curves of Declinometers Nos. I. and II.; comparing them with the same period at Singapore, we observe a certain degree of similarity, the morning maximum being at the same hour, the minimum being one hour later; the curves of the two declinometers differ slightly with each other: Sambooanga is on the line of minimum intensity.

The next curves are those of Batavia during the spring months; their resemblance to the spring curve of Singapore given in Part 2 of Plate VI. is very striking; the morning and afternoon maxima and the morning minimum being at the same hours at both places: Batavia is 14° south of the line of minimum intensity.

The next curves in Part 1 of Plate IV. are the Sarāwak summer curves; there is a considerable resemblance to the curves at the same period at Singapore, the morning minimum being one hour later; the position of Sarāwak is exactly the same as Singapore relatively to its position south of the line of minimum intensity. The

* The sun is longer to the south of the line of minimum intensity than it is to the north. Singapore is in north latitude 1° 18′, and as the line of minimum intensity crosses the meridian of Singapore in about 8° north latitude, the sun is to the south of it considerably more than half the year.

last three curves of Plate I. are the Keemah curves of the latter end of June or commencement of July; their morning maximum and minimum at 19 hours, and at noon, correspond with the same periods at Singapore.

At the top of Part 2 of Plate IV. containing the winter stations, the curves of the five declinometers are drawn to the same scale, viz. 1′ of arc to 0·35 of an inch: there may be seen from these curves, the extreme difference likely to occur amongst instruments observed nearly simultaneously; whilst these curves are similar, they are not identically the same; the observations were not taken at the same instant, but one after the other in the order of the declinometers*. The curves of Pulo Peesang in the same Plate, are similar to the Singapore February curve. The Carimon and Booăya curves are similar to one another, but the maximum in the afternoon is earlier than the corresponding maximum at Singapore. Part 1 of Plate V. is the continuation of the winter curves; the curves of the three declinometers at all the stations of Nicobar, Penang, Pulo Dinding, Batavia and Padang, agree well with the same winter period at Singapore.

In Part 1 of Plate V., at the hours of 6 and 7, there is observable in some instances a want of uniformity in the progression of the curve; in some instances no difference is perceptible, in others a minimum. On referring to Plate V. we find there is a minimum at Singapore in January, exactly similar to the minima shown in some of the curves of Part 1 of Plate V., and at the same hours.

In Part 2 of Plate V. are given the curves of the stations where the instruments were observed during the equinoctial months, both in spring and in autumn. The Madras curve, when compared with the Singapore curve, has its morning maximum and minimum at 20 hours and at noon; at Singapore at 18 and at 22 hours, two hours earlier. Madras is near the line of minimum intensity.

The observations at Bencoolen were taken for a few days at the end of August and at the commencement of September, it is therefore difficult to say to which month they belong; they agree well with the Singapore August curve. The next curves in the Plate are those of Batavia in March; they are exactly similar to the Singapore curve in March.

The Cocos curves taken in September agree well with the Singapore September curve; the form of the morning curve is identical, and the time of the afternoon maximum; but they differ in the afternoon maximum at the Cocos, having a greater range than the morning maximum; the progression of the magnet westward being subsequently more rapid till between the hours of six and seven, when there is the same faint minimum expressed as in the January curve at Singapore. Noting therefore those curves which are in accordance or differing but slightly from the Singapore

* The observation of No. IV. at 3 A.M. has been omitted in the curve, as on referring to the observation book the series was found to be broken on one day in November; but the observation at 3 A.M. was entered, and as the scale reading was unusually low, it has reduced the mean reading at 3 A.M., or at 15 hours lower than it should be.

curves during similar periods, we find only two which differ materially from the Singapore curves at similar periods of the year; one of the stations, Moulmein, being considerably to the north of the line of minimum intensity, the other, Madras (not differing so much), in its immediate vicinity. Sambooanga and Nicobar are indeed likewise close upon the line of no dip or minimum intensity, yet they agree generally with the Singapore curves. It is to be observed, that as we proceed north and approach the line of minimum intensity, the similarity to the Singapore curves becomes more faint; this may be seen on inspection of the Plates, where the most southerly stations, the Padang, Batavia and Cocos curves, agree exceedingly well with those at Singapore at similar periods*.

Bifilar Magnetometer.

The bifilar magnetometer is described at page 11 of RIDDELL's work; the apparatus is not very dissimilar to the unifilar; it consists of a tripod base with a fixed circular plate 5 inches in diameter, graduated so as to be read off by verniers to single minutes, carrying an upper revolving plate and two projecting arms for supporting the reading telescope and counterpoise weight; the magnet and bifilar suspension are inclosed, the former in a copper box, the latter in a suspension tube, 10 inches in length, carrying a circular plate, torsion circle and right and left hand screw-cylinder at its upper extremity, and the circle divided so as to be read off by verniers to 5′: the magnet is suspended by two portions of the same thread, and is maintained by a rotation of the upper extremities in a position at right angles to the magnetic meridian. The principal adjustments are the following, for the purpose of bringing the magnet, when suspended by the double thread, into a position at right angles to the magnetic meridian:—1st. To bring the line of detorsion of the threads to coincide with the magnetic meridian. This is effected by suspending the magnet by a single filament of untwisted silk; the telescope is turned until the centre division of the scale is on the wire; the instrument is clamped; the magnet is then introduced carefully with its bifilar suspension; the vernier of the torsion circle is turned until the centre division is again on the vertical wire of the telescope, and the plane of detorsion is in the magnetic meridian. The telescope which is fixed to the instrument is then turned 90° in azimuth; the vernier of the torsion circle is turned in the same direction through an angle (v) equal to 60°. The centre division of the scale is brought on the vertical wire by increasing or diminishing the interval of the threads; which is effected by turning the milled head of the screw-cylinder. The telescope is then turned back 90°; the torsion circle being turned back through the angle v; if the adjustment has been made correctly, the line of detorsion is again in the magnetic meridian;

* Some want of similarity to the Singapore curve at those stations where any difference is observable, may possibly arise in some degree from want of the observations extending over a sufficient number of days; but not altogether, for at Madras, where a difference is perceptible, the declinometers were observed for more than a month.

the accuracy of the adjustment is tested by turning the telescope 180° in azimuth, so as to reverse the direction of the magnet, or bring its north end to the south. The telescope is again turned 90° at right angles to the magnetic meridian, so that increasing readings denote a decrease of force; the vernier of the torsion circle is turned till the central division of the scale is again on the vertical wire. The magnet is then perpendicular to the magnetic meridian, and the instrument is in adjustment. Thus much was necessary for understanding the following adjustments; those at the Cocos and at Batavia only are given; the adjustments at the rest of the stations being precisely similar, since the same angle of torsion $v=60°$ was selected for every station.

Adjustment of the Bifilar at Batavia.

The bifilar was adjusted in the afternoon of the 8th of November 1846 at 3 P.M. With the single suspension thread, the scale read 100; the horizontal circle 82° 23′. The bifilar apparatus was then carefully substituted.

	Horizontal circle.	Torsion circle.	Scale.
	° ′	° ′	
Magnet direct	82 23	53 50	100
Magnet direct	172 23	113 50	100
Magnet direct	82 23	53 50	99
Magnet reversed	262 19	53 50	99
Magnet direct	172 23	113 50	92·3

Before taking down the instrument a fresh series was taken on the 7th of August 1847: premising that the reading 82° 23′ on the circle is direct, or the north end of the magnet to the north, and 262° 23′ is reverse, or the north end of the needle to the south; the following is the readjustment:—

	Horizontal circle.	Torsion circle.	Scale.
	° ′	° ′	
Magnet direct	172 23	113 50	132·8
Magnet direct	82 22	53 52	95·0
Magnet reversed	262 20	53 52	73·0
Magnet direct	82 30	53 40	85·0
Magnet reversed	262 50	53 40	78·0
Magnet direct	82 50	53 40	79·0
Magnet direct	172 50	113 40	121·0
Magnet direct	172 50	113 30	115·0
Magnet reversed	262 40	53 45	110·0
Magnet direct	82 40	53 45	99·5
Magnet direct	172 20	113 50	110·0

This small change of numbers is satisfactory, considering that the portable bifilar had been up for more than eight months.

Adjustment of the Bifilar at the Cocos.

The bifilar magnetometer was adjusted on the 27th of August, 1848. In the unifilar suspension the scale read 100·2; the bifilar suspension was then substituted.

	Horizontal circle.	Torsion circle.	Scale.
Magnet direct	50° 27′	233° 55′	99·3
Magnet direct	140 27	293 55	100·0
Magnet direct	50 27	233 55	96·5
Magnet reversed . . .	230 27	233 55	85·5
Magnet direct	140 17	293 55	95·3

The angle v or angle of torsion $=60°$. Thermometer 82°·6.

Value of a, *or of one Scale Division in terms of Radius.*

The variations of the horizontal intensity are obtained by multiplying the differences of the scale readings, or of their mean values (corrected for changes of temperature) by a constant coefficient

$$k = a \,.\, \cot v,$$

where a is the value of one scale division in terms of radius; as the horizontal circle by means of verniers read off to single minutes, I ascertained the value of a directly.

The first series gave the value of a' .	$=1'{\cdot}45$
The second series gave the value of a'	$=1'{\cdot}38$
The third series gave the value of a' .	$=1'{\cdot}43$
The fourth series gave the value of a'	$=1'{\cdot}44$
Mean . .	$1'{\cdot}433$

The other method consisted in knowing the length, of one division of the scale, and o the radius,

where $$a' = \frac{l}{2r} \times 3437'{\cdot}75,$$

$$l = \frac{1}{70} \text{ of an inch,}$$

$$r = 17{\cdot}19 \text{ inches,}$$

$$a' = \frac{1}{70} \times \frac{3437{\cdot}75}{34{\cdot}38} = \frac{100}{70} = 1'{\cdot}43.$$

$1'{\cdot}43$ has been the angular value assumed, and the value of a in terms of radius is

$$\cdot 0002909 \times 1'{\cdot}43 = \cdot 000415987,$$

and $k = a \,.\, \cot v = \cdot 0002402$ the value of one scale division in terms of the force. The scale readings or mean values are corrected for temperature according to the formula

$$f = f' - (t' - t)\frac{q}{k},$$

where f' and f= observed and corrected readings,

t' and t= observed and standard temperature,

q= change of magnetic moment of the bar for 1° of Fahr.

$k = a \cdot \cot v$, given above.

Coefficient of Temperature.—Determination of the Value of q.

The value of q was determined directly at all the principal stations by beat being gradually applied to the box at the time the instrument was in adjustment; by adopting this method before sunrise, the thermometer being at the lowest temperature, and the changes of force very trifling, I could ascertain at once the changes in the readings of the scale corresponding to the changes of the thermometer, and from thence the coefficient of temperature in terms of the force; a piece of cotton steeped in spirits of wine, ignited and applied carefully to the bottom of the box, gradually raised the interior temperature as indicated by the inclosed thermometer.

The following are the results at the commencement of August 1847 at Batavia; the results of the experiments at that station and at the Cocos are alone given, the results at all the other stations being precisely similar.

Coefficient of Temperature at Batavia.

Thermometer.	Differences.	Scale divisions.	Differences.
77°·6		76·8	
	5·0		6·3
82·6		103·1	
	2·4		0·9
85·0		104·0	
	3·5		3·2
88·5		107·2	
	1·0		0·9
89·5		108·1	
Sum	11·9		11·3

or one degree of temperature Fahr. for one scale division very nearly: this result agrees exactly with similar observations made at other stations.

Coefficient of Temperature at the Cocos.

To determine q or the coefficient of temperature the morning that the instrument was taken down, a piece of cotton dipped in spirit and ignited, was carefully applied to the bottom of the box, between 5 and 6 A.M., when the thermometer was at the minimum temperature and the changes of force but small, with the following results:—

Bifilar.		Thermometer.	
Scale.	Differences.	Fahr.	Differences.
86·1		75°·9	
	4·7		3·9
90·8		79·2	
	5·7		10·7
96·5		89·9	
	2·0		0·7
98·5		90·6	
	3·2		0·0
101·7		90·6	
Sum	15·6		15·3

Descending Scale.

97·0	4·7	83·6	7·0
92·0	5·0	79·6	4·0
89·6	2·4	77·6	2·0
87·3	2·3	76·6	1·0
Sum	14·4	Sum	14·0

Although the partial differences do not agree exactly, yet at the two extremes there is but little difference either in the ascending or descending scales of temperature. In the former, for an increase of 15°·3 of temperature the scale reading increased 15·6 divisions, and then fell back 14·4 scale divisions with a decrease of 14°; q therefore =·0002402 of the force. As these results are strictly in accordance with similar observations made at other stations, viz. at Sarāwak, Padang, &c., I have not had the least hesitation in assuming the value of q equivalent to one scale division: increasing scale readings denote an increase of temperature or decrease of force.

Oscillation or Variation of the Bifilar.

From page xlviii to lv inclusive, are given the oscillation, or more properly, the range of the horizontal intensity, given in detail in Table B; first, the mean oscillation of the horizontal intensity at all the stations comprised in the Survey; and at those stations where observations have been taken for more than a month, as at Batavia, Sarāwak, and Padang, the mean oscillation has been found from the monthly oscillations. At pages l and li are given the comparison of the observatory with the portable bifilar; but these are in scale divisions, and their values in terms of the force are different. The maximum range in the one case is 5·91 × ·000240 = ·0014, and in the other case 8·23 × ·000197 = ·0016 of the force; and the mean range is, of the portable bifilar, 2·48 × ·000240 = ·000595, and of the observatory bifilar 2·87 × ·000197 = ·000565 of the force*.

Singapore a Station for Comparison.

In order to have a fixed station where the hours of maxima and minima and extreme range may be known, the oscillation of the observatory bifilar is given in scale divisions at pages lii and liii for each of the seasons, for each of the months, and finally, the mean of each year.

* It is evident that the great difference between the portable and observatory bifilar magnetometers takes place in the morning, or when the atmosphere is most saturated with moisture. The observatory bifilar magnet being well protected, and suspended by silver wire, would not be affected by humidity. The portable bifilar, on the other hand, being more exposed, and the magnet suspended by filaments of silk, it is to be presumed that the thread would be somewhat affected by damp. It may here be observed, that the same silk threads for the bifilar suspension were in use during nearly the whole period of the Survey; the suspension thread was formed by placing three filaments of silk together, their torsion having been previously taken out, and after running them through a very weak solution of gum and water, wiping them quite dry; the threads thus treated lasted for more than three years.

Table B.

From page lvi to lxxxv are contained the results of the bifilar at each of the sixteen stations in the Archipelago; the stations are given from the most northern proceeding to the most southern, the observations themselves being omitted.

At the top of each page is printed the name of the station and the astronomical time; then follow the coefficients, the value of one scale division, and the value of q (the change of magnetic moment of the magnet for 1° of temperature in terms of the force); X the value of the absolute horizontal intensity; the zero of the month, which is the mean of the month uncorrected; and the standard temperature, to which the mean of the month is corrected. The results of the bifilar at each station are given in horizontal columns: the first contains the sums of the scale readings; the second the means; the third the temperature correction to the lowest mean reading of the thermometer; and as increasing scale readings denote a decrease of force, the corrections will be all subtractive; the fourth contains the corrected means; the fifth contains the variation of the force in scale readings, the highest scale reading being the minimum of force and considered as 0; and the sixth contains these scale divisions in terms of the force, one scale division being =·0002402 of the force. The last vertical column, or $\frac{\delta X}{X}$, is retained, since it is the difference between the zero and the mean value of the daily means corrected to 80°. Immediately below this table is given the mean results of the thermometer, the bulb of which is inserted in the copper box containing the bifilar magnet; the first column includes the sums; the second the means; and the third column the differences from the lowest mean temperature.

Curves.

Part 1 of Plate VII. contains the curves of the Bifilar at the Singapore Observatory for each month of the year in scale divisions, each scale division being ·000197 of the force drawn to 0·35 of an inch.

Part 2 of Plate VII. is drawn to the same scale, and contains the mean of the four seasons, the mean of each year, and the general mean of the three years. The general march of these curves is exceedingly simple, having but one single progression; the maximum occurs at either 22 or 23 hours, the autumn and winter curves having generally their maximum at the former, the spring and summer curves at the latter hour. The minimum occurs at 10 or 11 hours, the minimum in autumn and in winter being likewise one hour earlier than the minimum in spring and summer; the extreme range in spring and autumn being greater than in summer and in winter.

Plate VIII. contains the curves at the stations where the portable bifilar was observed; three stations having been omitted, as the curves of these instruments observed but for a few days would cause some confusion by crowding the Plate: there appears to be exactly the same similarity observable between these and the Singapore curves to which they are referred, the maximum occurring sometimes as late as noon;

but the curves at the winter stations, as at Singapore during the same period, being distinguished by the intensity reaching its maximum earlier by one hour than in spring.

The curves in Parts 1 and 2 of Plate VIII. are both drawn to the same scale, viz. one scale division (=·000240 of force) to 0·29 of an inch. The curve rising denotes an increase of force. The curves of the bifilar showing the changes of horizontal intensity, appear to partake, every one, of the same character as the horizontal intensity at Singapore.

Table C.—*Dry and Wet Bulb.*

The dry and wet bulb instrument was made by Cary; it was small but accurate, and was in use throughout the Survey; but the wet-bulb thermometer was broken in crossing from Moulmein to Madras, and at the latter station another thermometer was substituted in lieu of it.

Explanation of Table C.

The results of the dry and wet-bulb thermometers are contained in Table C, from page lxxxvi to cvii inclusive. The mean variation or range of the dry thermometer is given in the General Table at pages lxxxvi and lxxxvii. At pages lxxxviii and lxxxix are given the mean variation of the wet thermometer.

At pages xc and xci are given the mean variation of the tension and vapour, and at pages xciv and xcv the mean degree of humidity of the air at the different stations.

The Tables containing only the mean results of the observations commence at pages xcvi and xcvii. The dry and wet-bulb thermometers at each station are given in succession.

In the first line of each set is given the mean of the number of days observed, in the second line the diurnal variation; then follows the mean of the wet-bulb thermometer, the diurnal variation, and lastly, the tension or elastic force of vapour in inches of mercury. The formula for the tension of vapour at the dew-point is

$$f''=f'-\frac{d}{88},$$

where d is the difference between the dry and wet bulb, and f' the tension of vapour at the temperature of the wet bulb. The value of f' is given in Table V. of the Report of the Committee of Physics and Meteorology of the Royal Society. The quantity of humidity in the air is found by dividing the tension of vapour at the temperature of the dew-point by the tension of vapour at the temperature of the air, and the result gives the number of proportional parts of in humidity the atmosphere; and it is by this method that the Table at pages xciv and xcv is constructed. The Tables of the dry and wet bulb are concluded at pages cvi and cvii.

Curves.

The curves corresponding to these Tables are laid down in Plate IX.; but the standard thermometer for the dry bulb is substituted. The curves are drawn to a scale of 10° of temperature to 0·35 of an inch.

Remarks.

The curve of the dry thermometer consists but of a single progression, the minimum being usually at 6 A.M., the maximum at noon. The curve of the wet thermometer consists likewise but of a single progression, its maximum and minimum occurring at the above times; the diurnal variation of the tension of vapour at pages xc and xci at the different Survey stations is very irregular; the curve usually consists of but a single progression, and is very similar to the wet bulb. The minimum is usually at 6 A.M., the maximum being at noon; the greatest range extending from 0·1 to 0·26 of an inch of the barometer. The irregularity occasionally indicated may be owing to the shortness of the period during which the instrument was observed. At those places where the dry and wet bulb were observed for more than a month the curve is regular. Throughout the Archipelago the minimum of tension of vapour usually occurs at 6 A.M., the maximum being at noon; a remarkable exception to this takes place at Madras, where the minimum is observed at noon; it appears to be explicable from the circumstance of the remarkable dryness of the air at Madras in August and September compared with that of the Archipelago generally; the dry thermometer at Madras ranges 15°·5 during the day from 6 A.M. to noon, or 1 P.M.; at which time it is at its maximum, as also the difference between the dry and the wet bulb. After 1 P.M. the dry thermometer gradually falls, and the difference between the dry and wet bulb diminishes, whilst the wet-bulb thermometer is still rising, very slowly, till 3 P.M.; consequently the tension of vapour increases so that the minimum elastic force occurs at noon, and the maximum some time in the afternoon.

The mean elastic force of the tension of vapour varies from 0·8 to 0·9 of an inch of the mercurial column.

The range of the humidity in the atmosphere, given at pages xciv and xcv, shows a single progression only, the minimum being at noon, the maximum early in the morning; in some instances the air is saturated with moisture at 6 A.M.

At Moulmein and at Madras, where the air was driest, and just previous to the N.E. monsoon at the latter and the S.W. monsoon at the former place, the mean quantity of humidity varied from 66 to 68 parts, complete saturation being 100; in the space included in the Survey the air is always loaded with moisture, and it is a tolerable approximation to the truth to state, that throughout the Archipelago the minimum quantity of humidity is 0·75, the maximum 0·85, and the mean quantity 0·80; complete saturation being =1·0.

The following Table contains the stations, their latitudes and longitudes; the mean

date of observation; the number of days and the number of hours of each day the instruments were observed; the mean of the dry and wet thermometer, and of the tension of vapour; determined in two ways,—1st, by dividing by the number of hours during which the instruments were observed, and 2nd, by the system of equal intervals, a method for determining the mean value where the continuity of hourly observation is broken during the day, as generally occurred in the present instance.

Dr. Lloyd, in a paper on the mean results of observation, has shown that the error committed by taking the mean of any three equidistant hours as the mean temperature of the day, does not exceed 0°·26. In the following Table, in the column containing the mean by equal intervals, three sets of equidistant hours have been taken for finding the mean, viz. 3, 4, and 5 A.M.; 11 A.M., noon, and 1 P.M.; 7, 8, and 9 P.M. At those stations, where the instruments were observed during the twenty-four hours, a direct comparison can be instituted for ascertaining the correctness of this mode of finding the mean; at Sarāwak for three and at Batavia for four months, the means by each method are nearly identical. The mean temperature, as shown by the dry bulb, is about 80°; the mean of the wet bulb is between 76° and 77°; and the mean elastic force or tension of vapour throughout the space included in the Survey, varies from 0·8 to 0·9 of an inch of the barometric column.

Table showing the Means of the Dry and Wet Thermometers and of the Tension of Vapour, by Dr. Lloyd's method of equal intervals, and by dividing by the number of hours observed, and the difference in each case.

Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours.	Dry Thermometer.			Wet Thermometer.			Tension of Vapour.		
						Mean by equal intervals.	Mean by number of hours.	Diff.	Mean by equal intervals.	Mean by number of hours.	Diff.	Mean by equal intervals.	Mean by number of hours.	Diff.
Moulmein ...	16° 29′ 46″ N.	97° 45′ 30″ E.	Mid. of April	7	19	86·1	88·3	+2·2	78·0	78·5	+0·5	·853	·846	−·007
Madras	13 04 09	80 16 00	Begin. of Sept.	34	19	84·3	85·2	+0·9	76·6	76·6	0·0	·811	·801	−·010
Nicobar	9 10 12	92 48 23	Begin. of Feb.	5	19	79·3	80·5	+1·2	75·8	76·6	+0·8	·839	·855	+·016
Samboanga .	6 54 20	122 13 45	End of May.	6	19	80·5	82·2	+1·7	76·4	77·6	+1·2	·847	·877	+·030
Pulo Penang.	5 25 36	100 24 38	End of Jan.	5	19	80·6	81·2	+0·6	77·0	77·3	+0·3	·873	·876	+·003
Pulo Dinding	4 12 48	100 32 52	End of Jan.	3	19	82·7	83·2	+0·5	76·6	77·1	+0·5	·838	·844	+·006
Sarāwak.....	1 33 54	110 29 00	Mid. of June.	26	24	79·8	79·6	−0·2	77·8	77·7	−0·1	·913	·911	−·002
			Mid. of July.	27	24	79·0	78·9	−0·1	76·9	76·9	0·0	·886	·885	−·001
			Mid. of Aug.	19	24	79·0	78·8	−0·2	76·7	76·6	−0·1	·877	·874	−·003
Keemah	1 21 55	125 07 59	End of June.	10	19	80·4	81·1	+0·7	76·6	77·0	+0·4	·863	·865	+·002
Pulo Peesang	1 27 53	103 19 15	Mid. of Jan.	5	18	80·6	80·8	+0·2	77·5	77·9	+0·4	·892	·905	+·103
Singapore ...	1 18 32	103 56 30	End of Nov.	16	19	80·3	80·3	0·0	77·1	76·9	−0·2	·876	·869	−·007
			Begin. of Dec.	14	19	80·2	80·1	−0·1	76·4	76·2	−0·2	·851	·843	−·008
Padang	0 58 58 S.	100 31 15	End of Oct.	13	19	78·5	79·7	+1·2	75·9	75·7	−0·2	·816	·828	+·012
			Mid. of Nov.	26	19	79·2	80·2	+1·0	75·4	76·0	+0·6	·828	·835	+·007
			Mid. of Dec.	26	19	79·5	80·6	+1·1	75·3	75·9	+0·6	·820	·826	+·006
			Begin. of Jan.	13	19	79·8	80·9	+1·1	76·1	76·7	+0·6	·848	·855	+·007
Bencoolen ...	3 53 54 S.	102 28 45	Begin. of Sept.	5	19	78·1	79·3	+1·2	76·3	77·0	+0·7	·869	·865	−·004
Batavia	6 09 52	106 58 00	Mid. of Nov.	19	24	80·3	80·2	−0·1	76·8	76·8	0·0	·866	·866	·000
			Mid. of Dec.	26	24	79·7	79·7	0·0	76·6	76·5	−0·1	·866	·859	−·007
			Mid. of Jan.	25	24	79·5	79·8	+0·3	76·3	76·4	+0·1	·852	·854	+·002
			Mid. of Feb.	24	24	79·5	79·5	0·0	76·8	76·8	0·0	·875	·874	−·001
			Mid. of March	27	19	80·5	81·2	+0·7	77·2	77·6	+0·4	·882	·888	+·006
			Mid. of April	26	19	80·5	81·1	+0·6	77·0	77·3	+0·3	·874	·877	+·003
			Mid. of May	26	19	80·2	80·9	+0·7	76·5	76·8	+0·3	·858	·859	+·001
			Mid. of June	26	19	80·0	80·7	+0·7	75·4	75·7	+0·3	·815	·817	+·002
Cocos	12 05 38	96 50 30	Mid. of Sept.	26	19	79·6	79·5	−0·1	75·0	75·0	0·0	·802	·803	+·001

Some doubts have arisen as to the value of the dry and wet bulb as an instrument

for measuring approximately the degree of humidity in the atmosphere; and Colonel Sykes, F.R.S., has mooted the question in a very interesting paper on the Meteorology of India, which has been lately published in the Philosophical Transactions: one of the sources of error supposed to be peculiar to this instrument, although easily remedied if discovered, is the too close proximity of the wet bulb to the dry bulb, the consequent depression of the latter, the difference of the two thermometers or the value of d consequently diminishing, and the resulting tension of vapour greater than it ought to be. I do not know the exact distance that the two bulbs were apart in Cary's little instrument; at most 2 to 2½ inches, and both fixed to one stem. The following are the results of a comparison between the Standard Thermometer and Dry-Bulb Thermometer at all the stations; and it will be seen, on inspection of the following Table, how very slight are the differences between the two thermometers*.

Station.	Month.	Mean by the number of hours.		Difference.
		Standard Thermometer.	Dry Thermometer.	Standard − Dry Thermometer.
		°	°	°
Moulmein	April	88·4	88·3	+0·1
Madras	September	85·2	85·2	0·0
Nicobar	February	80·9	80·5	+0·4
Sambooanga	May	82·5	82·2	+0·3
Pulo Penang	January	81·7	81·2	+0·5
Pulo Dinding	January	82·6	83·2	−0·6
Sarawak	June	79·6	79·6	0·0
	July	78·8	78·9	−0·1
	August	78·7	78·8	−0·1
Keemah	June	81·5	81·1	+0·4
Pulo Peesang	January	81·5	80·8	+0·7
Singapore	December	79·8	80·2	−0 4
Padang	October	80·5	79·7	+0·8
	November	80·8	80·2	+0·6
	December	81·3	80·6	+0 7
	January	81·7	80·9	+0·8
Bencoolen	September	79·3	79·3	0·0
Batavia	November	80·3	80·2	+0·1
	December	79·8	79·7	+0·1
	January	80·1	79·8	+0·3
	February	79·6	79·5	+0·1
	March	81·3	81·2	+0·1
	April	81·3	81·1	+0·2
	May	81·2	80·9	+0·3
	June	81·0	80·7	+0·3
Cocos	September	79·2	79·5	−0·3

Standard Barometer and Portable Barometer, and Adjustments.

At the principal stations the large Standard Barometer was in use; but at some the Portable Barometer was observed, from the greater trouble and risk attending

* At Padang the differences are the greatest, and as these appear to be constant at the same station, they are probably due more to the relative position of the Standard Thermometer and Dry Bulb, than to the proximity of the latter to the Wet Bulb.

the carriage of the Standard. The Standard was used at the following places:—at the Cocos, at Batavia, at Padang, at Singapore, at Keemah, at Sarāwak, and at Sambooanga.

The Standard Barometer was made by NEWMAN; diameter of the tube 0″·532; the correction to be applied for capillary action +·003″. The zero-point consists of a fine conical point brought to touch the surface of the mercury; this is an adjustment which we are instructed to make at each observation; but throughout the Survey the conical point or zero-point, being once accurately adjusted, was never subsequently touched; the capacity of the cistern is so much greater than that of the tube, that the variation of the barometer in the Tropics being not more than $\frac{1}{10}$th of an inch, the level of the cistern would be but little affected thereby. The internal diameter of the cistern is about 4 inches; the relative areas of the tube and cistern are as 0·25 to 16, or as 1 to 64; and as the barometric column varies to the extent of $\frac{1}{10}$th of an inch, the cistern would be affected to $\frac{1}{640}$th of an inch, and the quicksilver therefore would rise above or sink below the mean position $\frac{1}{1280}$th of an inch; a space which a very accurate observer might be able to detect between the conical point and a very bright surface, but not with the quicksilver in the barometer now in question, as the surface was covered with a thick film, and the glass cistern was somewhat dingy; for this reason, after one adjustment very carefully made at noon, this being about the time of the mean, the zero point of the barometer was not further touched during the whole series of observations; and I never could detect at the hour of maximum and minimum, viz. at 9 or 10 A.M., and at 3 or 4 P.M., any difference in the relative position of the conical point to the surface of the mercury, and therefore no correction has been applied to the neutral point determined at noon.

The Standard Barometer was by no means tight, and therefore imperfectly portable: when moving from one place to another, the quicksilver was constantly escaping by the wooden collar at its junction with the tube; this loss was supplied with fresh mercury, strained through leather and poured into the cistern; and as no air could ever be detected in the tube, the instrument was perfectly serviceable throughout the whole of the Survey. The leakage at the collar was by no means peculiar to this barometer, as I have discovered it in others by the same maker.

The Portable Barometer, made by CARY, was in use at a few stations during the Survey; I had filled it very carefully at Singapore; in the comparisons made with it and the Singapore Standard Barometer, it was generally a little lower; but as it had not exactly the same range, the correction would not be constant, and therefore no correction has been applied. The diameter of the tube, which dimension I obtained from Mr. CARY, is between 0·27 and 0·28 of an inch; the correction to be applied for capillary action = +0″·023; the scale is marked on brass to the twentieth of an inch, and can be read off by a vernier to the thousandth of an inch, being similar in this respect to the Standard Barometer. The gauge-point or zero-point is a slit in the iron cistern at its upper surface; the quicksilver, being pressed up by means of a screw applied to the leathern bottom of the cistern, is raised till the light is no longer seen

through the slit, and the level of the quicksilver in the cistern is then at that point from which the scale is laid off; there is therefore no correction for neutral point: this instrument was well made and well finished, and has yielded at all times exceedingly satisfactory results.

Explanation of the Table D.

The observations made with the barometer are contained in Table D. from page cviii. to cxxi inclusive.

At pages cviii and cix are given the mean variation or oscillation of the barometer; at pages cx and cxi the mean variation of the gaseous pressure or dry column of air.

From page cxiv to cxxi inclusive, are contained the mean results of the barometer at each station: each set contains in the first line the mean of the barometer uncorrected; then the barometer corrected to 32°; and thirdly, the gaseous pressure which is deduced by subtracting from the barometric column the tension of vapour.

Curves.

The curves of the barometer corrected to 32°, are contained in Plate X. The curves are drawn to a scale of ·01 of an inch of barometric pressure to 0·30 of an inch linear measure: the curve rises with the increase of pressure.

Plate XI. contains the curves of the variation of gaseous pressure drawn to the same scale, viz. ·01 of an inch of barometric pressure to 0·30 of an inch linear measure: the curve rises with increase of pressure.

Remarks.

The barometric curve has a double progression, a principal maximum and minimum at 9 A.M., and at 3 and 4 P.M.; and a secondary maximum and minimum at 10 P.M. and 4 A.M. The intervals between the successive maxima and minima are nearly equal, and the degree of parallelism between all the curves is very striking; the range or variation appears to be nearly similar, and the hours of maxima and minima are identical; one exception occurs at Madras, the maximum taking place at the same time, but the minimum at 5 P.M., two hours later than the minimum generally throughout the Archipelago.

The variation of the gaseous pressure is given in Plate XI.; it appears to have, like the barometric curve, a double progression, but the principal maximum and minimum occur earlier; the A.M. minimum is more faintly expressed, with an interval of three or four hours only between the morning minimum and the morning maximum. The curve is likewise more irregular than the barometric, and the range is greater; only a few of the curves are given, to prevent confusion from over-crowding, and those places have been selected where observations have been taken for upwards of a month.

The following Table contains, by Dr. LLOYD's method of equal intervals, the means of the barometer uncorrected, the barometer corrected to 32°, and the mean of the gaseous pressure; each mean being the result of three sets at equidistant hours, viz. 3, 4, 5 A.M.; 11 A.M., noon, 1 P.M.; 7, 8. and 9 P.M. The mean throughout the Archipelago, of the barometer corrected, is 29·80 to 29·90 English inches; the range or variation being a little more than a tenth of an inch. The mean of the gaseous pressure is about 29 inches; the variation being nearly double that of the barometric pressure, and amounting to about two-tenths of an inch.

Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours.	Mean of the barom. uncorrected.	Mean of the barom. corrected to 32°.	Mean of gaseous pressure.
						28 English inches + the numbers in the Table.		
						in.	in.	in.
Moulmein ...	16° 29′ 46″ N.	97° 45′ 30″ E.	Middle of April	7	19	1·897	1·766	0·913
Madras	13 04 09	80 16 00	Beginning of September	34	19	1·807	1·681	0·806
Nicobar	9 10 12	92 48 23	Beginning of February	5	19	2·052	1·937	1·098
Sambooanga	6 54 20	122 13 45	End of May	6	19	1·997	1·863	1·013
Pulo Penang	5 25 30	100 24 38	End of January	5	19	2·005	1·885	1·013
Pulo Dinding	4 12 48	100 32 52	End of January	3	19	2·114	1·994	1·156
Sarāwak	1 33 54	110 29 00	Middle of June	26	24	1·997	1·864	0·952
			Middle of July	27	24	1·985	1·854	0·968
			Middle of August	19	24	2·009	1·879	1·002
Keemah	1 21 55	125 07 59	End of June	10	19	2·016	1·880	1·018
Pulo Peesang	1 27 53	103 19 15	Middle of January	5	18	2·074	1·955	1·080
Singapore ...	1 18 32	103 56 30	End of November	16	19	2·050	1·914	1·038
			Beginning of December	14	19	2·037	1·905	1·053
Padang	0 58 58 S.	100 31 15	End of October	13	19	2·045	1·912	1·097
			Middle of November ...	26	19	2·040	1·907	1·079
			Middle of December ...	26	19	2·005	1·873	1·053
			Beginning of January...	13	19	2·017	1·883	1·035
Bencoolen ...	3 53 54	102 28 45	Beginning of September	5	19	1·974	1·862	0·993
Batavia	6 09 52	106 58 00	Middle of November ...	19	24	1·994	1·860	0·992
			Middle of December ...	26	24	1·995	1·862	0·996
			Middle of January	25	24	2·001	1·868	1·016
			Middle of February ...	24	24	1·988	1·856	0·981
			Middle of March	27	19	2·015	1·876	0·994
			Middle of April	26	19	2·010	1·875	1·001
			Middle of May	26	19	2·009	1·873	1·016
			Middle of June	26	19	2·003	1·868	1·054
Cocos	12 05 38	96 50 30	Middle of September ...	26	19	2·089	1·958	1·155

Standard Thermometer.

This instrument, made by NEWMAN, was used in the observatory at Singapore till the end of the year 1845, and I then took it with me on the Survey. The scale is marked off to half-degrees, each degree being 0·11 of an inch, so that the thermometer is read off easily to tenths. In marking off the scale, an error has been committed in omitting one degree from 90° to 95°, so that 95° is only 94°; the divisions of the scale are all equal, and therefore the mistake occurring in the numbering only, one degree has always been deducted from the observed reading of the thermometer when it stood at 95° or above that temperature. The standard thermometer

was usually attached to the pole of the tent, or else to the back of the post to which the standard barometer was fixed.

Explanation of Table E.

The results of the observations with the Standard Thermometer are contained in Table E., from page cxxii to cxxix inclusive. At pages cxxii and cxxiii are given the diurnal variation of the Standard Thermometer. The remainder of Table E. contains the mean results of the Standard Thermometer; each set contains, in two lines, the mean hourly readings and the diurnal variation of the Standard Thermometer.

Curves.

The curves of the Standard Thermometer have already been noticed in speaking of the dry bulb.

Remarks.

There is but one maximum and one minimum in the twenty-four hours, viz. at 2 and at 18 hours. The oscillation or range varies, but the smallest is at Singapore, where the standard thermometer was placed inside the observatory, but exposed to a current of air passing through the building. The range was greatest at Moulmein and at Padang; but as at these observatories the observations were taken under canvas only, the direct influence of the sun's rays was very great. At Moulmein the temperature of the observatory was so hot as to be nearly unbearable, although the thermometer only reached 105°: at the commencement of the Introduction I gave a short statement of the materials with which each observatory was constructed, that, in recording the height of the thermometer, the circumstances under which it was observed should be taken into consideration: the difficulty in tropical climates of ascertaining correctly the temperature of the air is very great; the most difficult points to be determined appear to be; the size of the building, the height of the roof and the nature of the materials of which it is composed, in order that the thermometer shall give only the temperature of the air, and not in addition that of the building in which it is placed. If the building is small, if the roof is low and of good conducting materials, such as slates or tiles, the thermometer is too high by day, and probably too low at night; the only condition appears to be a lofty room, of large size, well-ventilated, and double-roofed with non-conducting materials. The observatories at Sarāwak, Singapore and Batavia were excellent in this respect: at all other stations the thermometer was not sufficiently screened from the above liabilities to error, and therefore the daily curve at some of the stations is too high, whilst the mean temperature is nearly correct.

Solar and Terrestrial Radiation Thermometers.

In addition to these thermometrical observations, there was likewise in use, at the conclusion of the Survey, a Solar Radiation Thermometer, the bulb of which was

tinged of a dark purple colour, although not absolutely black. This instrument was placed on a table outside the tents and freely exposed to the sun. After the instruments in the tent were observed, the solar radiation thermometer was read off hourly, from 7 A.M. to 4 or 5 P.M., and the maximum of the day recorded, with the time at which it was observed, being generally 11 A.M., noon, or 1 P.M.

The minimum self-registering thermometer was placed on a table outside the tent at night, and the minimum temperature shown by the index read off at 7 A.M.

The subjoined Table contains the maximum solar radiation, and the mean at each station; the minimum and the mean of the self-registering thermometer exposed at night; and lastly, the mean of the standard thermometer, by dividing by the number of observations, and likewise by Dr. LLOYD's method of equal intervals, each result being the mean of three sets, at 3, 4, 5 A.M.; 11 A.M., noon, 1 P.M.; and 8, 9, 10 P.M.

Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours	Solar Radiation.		Terr. Radiation.		Standard Thermometer.		
						Maximum.	Mean.	Minimum.	Mean.	Mean by equal intervals.	Mean of the whole set.	Diff.
	° ′ ″	° ′ ″				°	°	°	°	°	°	°
Moulmein	16 29 46 N.	97 45 30 E.	Middle of April.	7	19	111·5	110·0	70·2	71·9	88·0	88·4	+0·4
Madras	13 04 09	80 16 00	Beginning of Sept.	34	19	115·0	104·7	74·0	76·6	84·3	85·2	+0·9
Nicobar	9 10 12	92 48 23	Beginning of Feb.	5	19	102·0	98·9	67·7	68·4	79·9	80·9	+1·0
Samboanga	6 54 20	122 13 45	End of May.	6	19	104·7	102·6	71·4	72·3	80·7	82·5	+1·8
Pulo Peenang	5 25 30	100 24 38	End of January.	5	19	105·8	103·0	70·8	71·9	81·3	81·7	+0·4
Pulo Dinding	4 12 48	100 32 52	End of January.	3	19	113·8	110·9	70·6	72·2	82·4	82·6	+0·2
Sarāwak	1 33 54	110 29 00	Middle of June.	26	24	.....	.....	.....	.....	79·8	79·6	−0·2
			Middle of July.	27	24	.....	.....	68·6	71·8	79·0	78·8	−0·2
			Middle of August.	19	24	.....	.....	69·3	71·6	78·8	78·7	−0·1
Keemah	1 21 55	125 07 59	End of June.	10	19	112·2	108·6	68·3	70·3	80·9	81·5	+0·6
Pulo Peesang	1 27 53	103 19 15	Middle of January.	5	18	.....	.....	.....	.....	81·3	81·5	+0·2
Singapore	1 18 32	103 56 30	Beginning of Dec.	30	19	107·7	98·3	67·6	71·1	79·8	79·8	0·0
Padang	0 58 58 S.	100 31 15	End of October.	13	19	.....	.....	69·4	70·6	79·2	80·5	+1·3
			Middle of November.	26	19	.....	.....	69·8	71·1	79·7	80·8	+1·1
			Middle of December.	26	19	.....	.....	68·5	70·8	80·3	81·3	+1·0
			Beginning of Jan.	13	19	.....	.....	.....	.....	80·5	81·7	+1·2
Bencoolen	3 53 54	102 28 45	Beginning of Sept.	5	19	.....	.....	69·8	71·2	78·4	79·3	+0·9
Batavia	6 09 52	106 58 00	Middle of November.	19	24	.....	.....	69·2	72·4	80·5	80·3	−0·2
			Middle of December.	26	24	.....	.....	69·8	72·6	80·3	79·8	−0·5
			Middle of January.	25	24	.....	.....	68·5	71·1	80·0	80·1	+0·1
			Middle of February.	24	24	.....	.....	70·7	73·6	79·6	79·6	0·0
			Middle of March.	27	19	.....	.....	69·2	72·9	80·9	81·3	+0·4
			Middle of April.	26	19	.....	.....	69·2	71·5	80·8	81·3	+0·5
			Middle of May.	26	19	.....	.....	67·4	69·9	80·7	81·2	+0·5
			Middle of June.	26	19	.....	.....	.....	.....	80·5	81·0	+0·5
Cocos or Keelings	12 05 38	96 50 30	Middle of September.	27	19	105·5	99·5	72·2	74·9	79·2	79·2	0·0

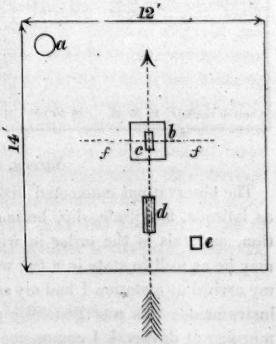
Survey, and Instruments employed.

The observations connected with the Survey relate to absolute determination, such as latitude, longitude, dip, horizontal intensity, and variation or magnetic declination, and this is the order in which the subject will be treated; but previously, it may be as well to state in a few words, how the Survey on land was conducted. On my arrival at a station I had my small tent pitched, for the reception of the magnetic instruments; this was generally put up the evening of my arrival; and the next morning at daybreak I commenced observing. The instruments in use were a 6-inch dip circle, a portable declinometer for magnetic declination and intensity, an altitude

and azimuth instrument, made by Robinson, and sent out on the first establishment of the observatories, and a chronometer (824), Arnold and Dent, which had been so long in use, that it was not to be trusted for a fixed rate. The first instrument set up was the portable declinometer; this instrument was tedious to adjust, in consequence of the suspension thread, to support the collimator magnet, being stronger than there was occasion for so as to obviate the necessity of frequent renewal; the stirrup with the brass weight attached to the suspension thread, was allowed to swing for more than a couple of hours; the opportunity was taken during the interval of determining the dip with four needles. At 8½ A.M. the dip observations being completed, the stirrup of the portable declinometer, by frequent small twists of the torsion circle having been brought to rest in the magnetic meridian, was finally in adjustment. The brass weight for taking the torsion out of the threads was removed, and the collimator magnet placed in the stirrup. The altitude and azimuth instrument was adjusted in rear of the collimator magnet, and in the direction of its axis, but always to the south of it, at a distance of about 4 feet. By 9 A.M., this instrument being also in adjustment, the copper damper was placed carefully in the oaken box containing the collimator magnet, by which the latter in a few minutes was brought to rest. During this short interval three or five altitudes of the sun were taken with the sextant and artificial horizon, and the corresponding times with the chronometer.

At 9½ A.M., the collimator magnet being at rest, altitudes of the sun were observed with the altitude and azimuth for magnetic declination or variation; these being finished, observations for horizontal intensity, both of deflection and vibration, were proceeded with and generally finished at 11½ A.M. At noon circummeridional altitudes of the sun were observed for latitude, and in the afternoon, if fine, equal altitudes were taken to confirm the morning sights. The tent was then taken down, the instruments packed up, and generally sent off in the evening, if practicable, to the next station.

The following is a rough diagram (not drawn to scale) of the relative positions of the instruments in the tent:—



a. The dip circle, removed at 8½ A.M.

b. Declinometer-box, with deflecting arms, *f*, *f*, for the determination of the absolute horizontal intensity.

c. Collimator magnet, in declinometer-box, suspended by three or four fibres of untwisted silk.

d. Telescope of altitude and azimuth.

e. Position of table on which the chronometer was placed.

Dimensions of the tent 12 × 14 feet.

Latitude.

The observations for latitude were usually taken, if the weather permitted, a few minutes both before and after noon: the instrument being previously in adjustment, the altitudes and times corresponding were taken immediately before or at noon, three times with the vertical circle direct, and three times at or immediately after noon with the vertical circle reversed; the latitude was found from these altitudes reduced to the meridian.

A Table of the Latitudes at the Cocos or Keeling Islands is subjoined, merely as a specimen of the working of the instrument; it is necessary to state, that in the observations for latitude by taking altitudes of the sun, the error of collimation was corrected by the reversal of the telescope on its axis; but in finding the latitude from altitudes of the stars, the instrument was clamped in the meridian, the altitude of the star taken as it passed the centre wire, and a correction applied for the error of collimation.

Date.	Latitude ⊙	Date.	Latitude ✱.	Name of ✱.
August 26.....	12° 05′ 21″ S.	August 28	12° 05′ 18″ S.	α Herculis.
27.....	06 15		05 32	α Ophiuchi.
31.....	06 10	September 10	05 07	γ Aquilæ.
September 7.....	05 30		05 30	α Aquilæ.
15.....	05 46		05 40	ε Aquarii.
23.....	05 19		05 20	μ Aquarii.
26.....	06 07	12	06 20	p Piscium.
27.....	05 58		05 40	s Piscium.
		13	05 10	s Piscium.
		14	05 30	μ Ceti.
			05 30	o Piscium.
		15	05 45	ζ 2 Ceti.
			05 20	μ Ceti.
		16	05 10	λ Tauri.
		17	05 28	γ Aquilæ.
			05 30	α Aquilæ.

Longitudes.

The longitudes were found chiefly from sights; but I am afraid they are not much to be depended upon, in consequence of the rate of the chronometer frequently changing; the following is the method I adopted, at any two places far apart, where I was able to determine the rate. I took the mean rate and applied it to the observations for longitude at the intermediate stations. At some of the principal points, where I remained for a considerable time, I was able to obtain sights of moon-culminating stars for longitude, as well as lunar distances; the longitudes obtained from moon-culminating stars with the altitude and azimuth instrument, were necessarily very rough, but they served as a check upon the chronometer.

The following observations were taken at the Cocos:—

Date.	Stars and Moon.	Mean difference between Greenwich and Cocos, ☀ and ☾.	Resulting Longitude East.
		m s	h m s
Sept. 6.....	δ Ophiuchi, ☾ I, μ Sagittarii, λ Sagittarii	14 09·86	6 27 18
8.....	σ and π Sagittarii, ☾ I, α 2 Capricorni	14 49·08	6 28 36
9.....	α 2 Capricorni, ☾ I, ε and μ Aquarii.....	15 00·13	6 26 31
10.....	ε and μ Aquarii, ☾ I, γ and δ Capricorni	15 11·14	6 27 48
12.....	☾ I, p and s Piscium	15 20·05	6 27 05
13.....	s Piscium, ☾ II.	15 27·42	6 26 45
14.....	☾ II., μ and o Piscium	15 44·21	6 28 23
15.....	o Piscium, ☾ II., ζ, ε and μ Ceti.....	15 59·04	6 27 43
	Mean Longitude		6 27 22

The mean longitude resulting from nine sets of lunar distances, was $6^h\ 26^m\ 47^s$; but these were not to be trusted, as the sum of the distance and the true altitudes of the ☉ and ☾ at each observation amounted to 180°, very nearly. I consider it my duty, however unsatisfactory may be the observations, to publish one set in detail, as their value, small or large, may thus be inferred; although but little could be expected from a small altitude and azimuth on an ordinary table stand, as a substitute for a transit instrument, it was better to depend upon these observations than upon the chronometer, which had been long in use, and which yielded such rates, on successive days at the Cocos, as the following:—

$+7^s{\cdot}7$, $+9^s{\cdot}1$, $+11^s{\cdot}4$, $+8^s{\cdot}8$, $+7^s{\cdot}8$, $+6^s{\cdot}7$, $+6^s{\cdot}7$, $+8^s{\cdot}4$, $+8^s{\cdot}9$,
$+8^s{\cdot}7$, $+8^s{\cdot}9$, $+9^s{\cdot}1$, $+9^s{\cdot}5$, $+12^s{\cdot}2$, $+10^s{\cdot}4$, $+9^s{\cdot}9$, $+8^s{\cdot}6$, $+8^s{\cdot}9$;

the mean rate being $+8^s{\cdot}19$; of course no dependence could be placed upon such rates as these for the longitude.

Dip or Inclination of the Needle.

The Dip Observations are contained in Table F., from page cxxx to cxxxix inclusive.

On commencing the Survey in 1846 I was not furnished with a dip circle; a Fox's dip circle had been stolen from the observatory at the latter end of 1845, and three dip circles had been sent, in 1844, to England to Mr. Barrow, but they had not then reached Singapore, having been detained at Bombay through some mistake.

In March 1846 I received a dip circle with four needles from Mr. Taylor, the then astronomer at Madras: the needles were very inferior; one of them, A 1 L, having a difference of 24° reading on the reversal of the poles: the observations with this needle should perhaps have been omitted. The correction to be applied to A 1 L was 28′, with only half the value assigned to it, which has been given to each of the other needles, and each recorded observation with the Madras circle is the mean of forty-eight readings. With the Madras dip circle I took observations at Singapore, in

Borneo, at Batavia, and the western portion of the island of Java; these observations are included in pages cxxx and part of cxxxi.

On my return to Batavia at the latter end of the year, I found the three dip circles, which, having been thoroughly repaired, had been sent out by Mr. Barrow; the observations are contained in pages cxxxii and cxxxiii*.

Before commencing the survey of part of Sumātra, I determined to make use of needles with their poles unchanged, and to apply a correction, if necessary, for the true dip, as the large magnets for reversing the poles were often brought in dangerous proximity to the small cylindrical magnets used on the Survey. Having determined the true dip at Padang with nine needles, I fixed upon Dip Circle No. 1 with three needles, A 1, A 1 L and A 2 L, by first combining A 1, A 1 L, and subsequently A 1 L with A 2 L.

The mean result gave me as a correction . . .	$+8'{\cdot}9$
The mean of the nine needles with the poles changed .	$=-18^\circ\ 31'{\cdot}7$
With the three combined as above and the poles unchanged	$18^\circ\ 40'{\cdot}6$
	$+8'{\cdot}9$

So that in the Survey in Sumātra, at page cxxxv in the last column, is given the corrected dip by subtracting $8'{\cdot}9$ from the mean of the three needles.

This series of three needles with poles unchanged and correction $+8'{\cdot}9$, terminates at Nātal in Sumātra.

On my return to Singapore in February 1848, a long series of observations was taken, to determine by direct means the difference in the inclination A.M. and P.M., the former being taken with four needles at 10 and 11 A.M., the hours of maximum horizontal intensity, and the latter at 4 P.M., the hour of minimum horizontal intensity; the poles of the needles employed were changed at the commencement or the termination of each day's observation, so that the A.M. and P.M. observations were taken with the needles under the same magnetic condition; two days consequently were necessary for the determination of the true dip. From the mean result at page cxxxiv, there is a difference of $0'{\cdot}8$ increase in the afternoon, whilst the probable error of the mean value of each set is the same, viz. $\pm 0'{\cdot}4$.

At the Cocos or Keeling Islands, the poles of the needles of Box No. 1 being unchanged, the correction to be applied to the three needles was as follows:—for A 1, $-3'{\cdot}0$; for A 1 L, $-6'{\cdot}0$; and for A 2 L, $-3'{\cdot}0$; equal value in determining the mean has however been given to these needles, as double the number of readings have been taken.

At Pulo Dinding the poles of the needles of Dip Circle No. 1 were again changed,

* There were originally four needles, A 1, A 2, A 1 L, A 2 L, to each dip circle numbered 1, 2 and 3; but three of the needles having soon become rusty, there were left three needles with Dip Circle No. 1, four needles with Circle No. 2, and two needles with Circle No. 3; and it was in consequence of Dip Circle No. 2 being complete, that it was used for the survey of Java.

when it appeared that for A 1, poles direct and poles reversed were nearly the same; for A 1 L, the correction to be applied to poles direct was $-16'{\cdot}3$, and for A 2 L, the correction to be applied was $-2'{\cdot}0$; and these have been the corrections made use of at page cxxxv for Dip Circle No. 1 at Singapore.

Inclination or Dip at Sea.

The observations at sea were made with a Fox's Dip Circle; the separate observations are not given, as they would occupy too much space; but the mean results are contained in a General Table at page cxxxvii, where the observations at sea have been corrected for the direction of the ship's head, for index correction (the poles being unchanged), and corrected with the whole of the dip observations to a mean epoch, viz. January 1, 1848. The details of swinging the ship, of finding the index correction, are not included in this report, but one example is given of swinging the Schooner at Keemah.

Correction for Direction of Ship's Head.

There were in all thirteen observations: from north to east, three; east to south, three; south to west, three; and west to north, four.

	Ship's Head.	Dip.	Mean Dip.
North to East	N.	11° 37′·5	11° 37′·2
	N.E.	11 35·0	
	E.N.E.	11 39·1	
East to South	E. by S.	11 33·7	11 33·6
	E.S.E.	11 40·8	
	S.S.E.	11 26·2	
South to West	S. by W.	11 29·7	11 33·7
	S.W.	11 33·3	
	W. by S.	11 36·2	
West to North	W. by N.	11 31·1	11 35·5
	W.N.W.	11 34·5	
	N.W.	11 39·5	
	N. by W.	11 36·8	

On shore, at Keemah, the mean of five observations by Fox's Dip Circle was 11° 28′·0, and as the Schooner bore E.S.E. the correction for distance would be $-1'$; the dip by this instrument at the ship would be $-11°\ 29'$, and the correction, therefore, for the direction of the ship's head and of local attraction, is, from north to east $+8'{\cdot}2$; east to south $+4'{\cdot}6$; south to west $+4'{\cdot}7$; west to north $+6'{\cdot}5$.

Index Correction.

True dip on shore from nine needles . . .	11° 02′·7
Dip from needle B. (Fox) as above	11° 28′·0
Index correction	+25·3

This instrument Colonel Sabine, R.A. had the kindness to send out to me, and I used it whenever an opportunity offered, but the Schooner was so small that it was difficult to take observations of inclination when there was any sea on. The needle B. was never removed from the box, and advantage was taken at every station of applying to the dip a fresh index correction. Fox's Dip Circle, sent out overland, was very roughly handled on its way out, so that the circle was no longer concentric to the axis of the needle. The observations were taken on a gymbal stand, the dip circle being leveled as accurately as possible, and twenty readings taken with the face of the circle to the east, and the same number with the face of the circle to the west. The inclinations at sea contained in the General Table, are the means of several groups of observations; for the dip being observed whenever it was calm, three or even five observations were taken repeatedly during the day when the weather permitted.

General Table, and Reduction of Observations to one common Epoch.

The General Table of Inclination on shore and at sea is given at pages cxxxvii, cxxxviii and cxxxix. The whole of the observations are reduced to one common epoch, viz. the 1st of January, 1848. At the Singapore Observatory observations were taken at two different periods, and with great care.

At the commencement of 1848 the dip was	−12° 56′·8
At the commencement of 1849 the dip was	−12° 59′·4
The difference nearly, of one year . . .	=−2′·6

These are valuable chiefly from the superior character of the instruments and dipping-needles. But going back to the first establishment of the observatory, the mean dip of the needle was—

At the end of 1841	−12° 43′·3
At the end of 1848, or commencement of 1849 . .	−12° 59′·4
	−16′·1

giving for the yearly change −2′·3.

The secular change at Madras can likewise be determined; for from the mean of twenty-two observations taken in July 1840,

The mean dip of the needle was	+7° 13′ 40″ N.
Twenty-nine observations in July and August 1849, gave	+7° 37′ 42″
Total difference in nine years	+24′ 02″

being 2'·7 per annum increase, or 0'·22 per mensem. This rate of 0'·22 per mensem is assumed as the correction to be added to observations taken prior to January 1848 to correct them to that epoch, and subtracted from observations taken subsequent to that date. This change at Madras is I believe strictly in accordance with the observations of Captain Ludlow of the Madras Engineers, the talented director of the magnetic establishment at that station. As the south end of the needle dips at Singapore and the north end at Madras, and the inclination is increasing at both stations, there must be at some intermediate spot a point of contrary flexure.

The method of observing on shore after the reception of the three new dip circles was never altered with those needles whose poles were changed; the circle being always in the magnetic meridian; two sets of readings were taken in each position of the needle, the usual eight positions being observed for the correction of instrumental error as follows: viz. needle direct and reversed for the non-coincidence of the magnetic axis with the axis of form; the circle east and the circle west for the correction of the zero of the vertical limb, and the same four positions with the poles changed to correct the error arising from the centre of gravity not coinciding exactly with the axle of the needle.

With a view of ascertaining the value of the observations of the inclination, I drew up the following Table of the probable error of a single determination, and of the probable error of the mean value of the inclination at some of the principal points of the Eastern Archipelago.

The first column contains the year and month; the second, the name of the station; the third, the number of needles; the fourth, the number of dip circles observed; the fifth, the number of observations; the sixth, the mean value of the dip; the seventh, the probable error of a single determination; and the eighth, the probable error of the mean value.

Year and Month.	Name of Station.		No. of Needles.	No. of Dip Circles.	No. of observations.	Mean value of the Dip.	Probable error of a single determination.	Probable error of the mean value.
March, 1846	Singapore		3	1	21	−12 47·7	±4·3	±0·9
July, 1846	Sambas	Borneo	3	1	6	14 26·5	4·2	1·7
	Pantiānak	Borneo	3	1	9	14 41·0	3·3	1·1
May and June	Sarāwak	Borneo	3	1	27	11 09·7	4·9	0·9
September, 1846	Batavia	Borneo	3	1	9	27 03·7	3·1	1·0
November		Borneo	6	3	6	27 02·4	2·0	0·8
November	Tegu	Java	12	3	19	28 42·5	1·8	0·4
November	Top of Gedé	Java	5	2	6	29 42·7	1·8	0·7
December	Chunjūr	Java	12	3	12	28 23·1	2·4	0·7
December	Sidang Bārang	Java	4	1	8	30 12·1	1·3	0·4
December	Bandong	Java	11	3	15	28 31·1	2·9	0·8
December	Garoet	Java	6	2	6	28 58·5	0·7	0·3
December	Permangpek	Java	4	1	8	30 11·8	0·9	0·3
February, 1847	Soorabāya	Java	4	1	8	28 50·2	3·8	1·3
March, 1847	Sūmenap		4	1	12	27 43·5	1·3	0·4
April	PuloKuneeang		4	1	12	27 23·6	2·3	0·7
May	Kedeeri		4	1	12	29 50·0	2·1	0·6
July	Batavia		9	3	44	27 08·2	1·8	0·3
September	Bencoolen		9	3	17	23 53·1	1·9	0·5
October	Padang		9	3	9	18 31·7	3·9	1·3
February, 1848	Singapore, A.M.		4	1	28	12 56·4	2·0	0·4
	P.M.		4	1	28	12 57·2	1·9	0·4
			4	1	56	12 56·8	2·0	0·3
May	Pulo Labooan		9	3	9	2 53·2	1·7	0·6
	Sambooanga		9	3	9	+ 1 19·3	1·6	0·5
June	Keemah		9	3	9	−11 02·7	1·7	0·4
August	Cocos		9	3	36	39 20	1·3	0·2
November	Singapore		9	3	80	12 59·4	2·8	1·3
January, 1849	Malacca		9	3	9	11 27·9	0·9	0·3
January	Pulo Dinding		9	3	9	7 33·9	2·2	0·7
January	Penang		9	3	9	4 55·5	1·6	0·4
February	Nicobar		9	3	9	+ 1 17·8	1·1	0·4
March	Hastings' Island		9	3	9	4 32·3	1·9	0·6
April	Moulmein		8	3	8	17 49·1	2·5	0·9
July	Madras		9	3	29	7 37·7	1·5	0·3

Horizontal Intensity.

The horizontal intensity was determined from four declinometers, viz. the small Observatory Declinometer at Singapore; the Induction or No. II; JONES's or No. III; and the Portable Declinometer.

The Observatory Declinometer with apparatus, consisted of a small gun-metal box, in which was suspended a needle 3 inches in length with mirror attached: two deflecting bars at right angles to the box, were marked off to 0·05 of a foot. A telescope and scale detached from the instrument, and put on a separate pillar, completed the apparatus, which was placed in a building near the magnetic observatory.

2nd. *The Induction or No.* II. *Declinometer.*—This instrument has already been described; the apparatus for deflection consists of two arms fixed at right angles to the box; they were of insufficient length, as the greatest distance at which the deflecting magnet could be placed was 1·4 foot. On measuring the angles of deflection,

the ivory scale was always made use of instead of the horizontal limb of the instrument; and the advantage gained by this was rapidity of observation.

Jones's, or No. III Declinometer, was received at the termination of the Survey; it was liable to derangement from the difficulty of clamping the limb securely; in other respects the instrument was a very great improvement upon No. II. Declinometer; the ivory scale had a greater range; the deflecting bar at right angles to the instrument was a strong brass scale, supporting a moveable stirrup on its upper edge, on which the deflecting magnet was placed, so that it could be moved backwards and forwards by sliding the stirrup along the scale: the great advantage of this arrangement consisted in the deflecting magnet never being touched, nor affected by the heat of the hand.

Six deflecting needles were used with the three declinometers, D 5, D 6, A 7, A 8, A 9 and A 10. D 6 was lost at Padang in Sumātra.

The Portable or No. IV. Declinometer, was used both for variation and for horizontal intensity; so that after altitudes of the sun and the magnetic axis of the collimator magnet had been observed, the instrument became available for observations of deflection and vibration; C 15 a collimator magnet, being suspended, and C 7 the deflecting needle. The angles of deflection were read off on the glass scale of the suspended magnet, the divisions of which were very coarsely cut.

Explanation of Table G.

The observations are contained in Table G. from page cxl to page cliii. The results are given in eleven columns. The first contains the date; the second, the station; the third and fourth, the suspended and deflecting magnets; the fifth and sixth, the distances at which the magnets were placed, with the corresponding angles of deflection; the seventh, the observed time of 300 vibrations; the eighth, the Declinometer; O standing for the Observatory, I for the Induction, J for Jones's, and P for the Portable Declinometer; the ninth and tenth, the values of m and X, m being the moment of free magnetism of the deflecting bar, and X the horizontal component of the earth's magnetic force; and the eleventh, the mean value of X.

Mode of Observation in determining the Horizontal Component of the Force.

The position of the deflected magnet was read off without the deflecting magnet, both at the commencement and at the end of the observations, and the change which had occurred in the declination in the interval was thus shown without the necessity of a subsidiary instrument. The change of declination observed was spread over the observations, on the supposition that it had been uniform. The deflecting magnet was placed on the brass scale to the west of the declinometer, and moved successively to four or eight distances, with the marked end of the needle to the west and to the east. The needle was then placed to the east of the deflected magnet, and a similar operation performed. This concluded the experiments of deflection.

To determine the time of one vibration, 360 were observed, and care was taken that the vibrations of the deflecting needle should be limited to an exceedingly small arc.

Formulæ for the Determination of m and X.

Deflection.—The value of $\frac{m}{X}$ is found for each distance by the formula

$$\frac{m}{X}=\frac{1}{2}r^3 \tan a \cdot \frac{1}{1+\frac{P}{r^3}},$$

where

$$P=-\frac{r^3 r_1^5 \tan a_1 - r_1^3 r^5 \tan a}{r_1^5 \tan a_1 - r^5 \tan a},$$

r and r_1 being two distances at which the deflecting magnet is placed, a and a_1 the corresponding angles of deflection.

Vibration.—From the experiments of vibration,

$$mX=\frac{\pi^2 k}{T^2},$$

where π is the ratio of the circumference of a circle to its diameter, k the moment of inertia of the magnet and stirrup, T the time of one vibration.

To obtain the value of k, a cylindrical brass weight is attached at each end of the magnet,

and

$$k=k_1 \frac{T^2}{T'^2-T^2};$$

where k_1 is the moment of inertia of the magnet and attached weights, T the time of vibration with the magnet and stirrup only, T' the time with the weights attached,

and

$$k_1=\left(\frac{1}{2}l^2+r^2\right)p;$$

in which l=the interval between the points of suspension of the weights, r the radius of the brass cylinders, and $2p$ their weight.

Determination of the Coefficients.

In finding the values of m and X, it is necessary to determine certain constants; such as (1) the value of one division of the scale of the suspended magnet; (2) the coefficient of temperature of the deflecting magnet; (3) its moment of inertia; (4) the value of P.

(1.) *Value of one division of the scale.*—In the Singapore Observatory Declinometer, the value of one scale division was determined by the formula

$$d'=\frac{l}{2r}\times 3437'{\cdot}747:$$

the results alone are given.

November 22, 1845.—Value of one scale division . . . . . $=1'{\cdot}002$

$$1+\frac{\text{H}(=\text{torsion force})}{\text{F}\,(=\text{magnetic directive force})} \quad . \quad . \quad =1{\cdot}0004$$

March 21, 1846.—Value of one scale division . . . $=59''{\cdot}983=1'$ nearly,

$$1+\frac{\text{H}}{\text{F}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad =1{\cdot}0004$$

March 7, 1848.—Value of one scale division . . . . . $=1'{\cdot}0081$

$$1+\frac{\text{H}}{\text{F}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad =1{\cdot}0007$$

On returning to the observatory, in December 1848, after an absence of several months, I found that the pillar supporting the instrument was slightly inclined, the foundation having been undermined, probably by white ants; I rebuilt the pillar, and the instrument being readjusted, the value of one scale division $=1'{\cdot}0005$.

The value of one scale division of the Induction Inclinometer has been already stated $=1'{\cdot}0$.

The value of one division of No. III. Declinometer was determined at Samboo-anga, May 31, 1848.

By measuring the scale, with the aid of the horizontal circle, the value of one scale division has been ascertained . . . . . $=1'{\cdot}0036$

and $$1+\frac{\text{H}}{\text{F}} \quad . \quad . \quad . \quad =1{\cdot}00037$$

The value of one division of C 15, the suspended collimator magnet of the Portable Declinometer, was determined from time to time; but the following are the results with two theodolites.

By the large altitude and azimuth, value of one scale division .	$=2'{\cdot}904$
By the small theodolite	$=2{\cdot}900$
Mean value	$2{\cdot}902$

The value of one scale division of C 7 the deflecting collimator magnet, was found to be $=2'{\cdot}342$.

(2.) *Coefficient of Temperature.*—The coefficient of temperature, or value of q, was determined by vibrating the needles in an oak box, and increasing the temperature of the room in which the magnets were vibrated. Perhaps the coefficient of temperature has not been sufficiently well determined; but as the standard temperature to which the magnets are reduced is 80°, and the temperature of the deflecting magnets never differed materially from this, a slight error in the determination of the coefficient would make no perceptible difference in the resulting value of X.

Experiments were carried on at Woolwich, at the end of last year, with one of the needles; the coefficient of temperature was determined for the cylindrical magnet

D 5 by the method of deflection, and the result coincided with the value of q found by vibration.

The following Table contains the determination of the value of q, or of the coefficient of temperature of the small magnets.

$q = \frac{T' - T}{T(t' - t)}$, in which t' and t are the two temperatures, and T' and T the corresponding times of vibration.

Date.	No. of magnet.	No. of vibrations.	T.	t.	No. of vibrations.	T'.	t'.	$t'-t$.	T'−T.	Value of q.	
1844.											
June 7.	D 5	720	86·5	341″·635	3600	121·3	343″·05	34°·8	1″·415	·000119	Mean of the solid magnets
May 28.	D 6	1080	86·6	339·47	1440	116·8	340·252	30·22	0·7825	·000076	$q = ·000105$.
	A 7	720	86·25	254·725	720	118·3	256	32	1·275	·0001565	
May 30.	A 8	720	86·5	315·08	1080	119	316·33	32·5	1·25	·000122	Mean of the hollow cylindrical
May 30.	A 10	720	87	266·755	1080	120	267·637	33	0·882	·0001	magnets $q = ·000322$.
June 7.	H 9	360	87	180·3	360	119·8	182	26·8	1·7	·000352	
June 14.	H 10	360	86·8	181·92	720	126	183·805	29·2	1·885	·000355	
June 27.	H 11	360	87	179·96	360	103	173·66	16·0	0·701	·000253	
1845.											
April 7.	C 7	756	88·5	423·1	360	109·7	427·00	21·2	2·28	·00025	

(3.) *Moment of Inertia.*—The moment of inertia was determined at different periods. The following Table contains the moments of inertia prior to the commencement of the Survey at the Singapore Magnetic Observatory.

Date.	Magnet.	Small weights. Time of 1 vibration from 360. Needle loaded, t'.	Small weights. Time of 1 vibration from 360. Needle unloaded, t.	Length of magnet in feet.	p_1, or weight of cylinder in grs.	r, or radius of cylinder in feet.	Moment of inertia $k_1 = \frac{1}{2}p_2 + r^2 \frac{t^2}{k = k_1 \frac{t^2}{t'^2 - t^2}}$	Large weights. Time of 1 vibration from 360. Needle loaded, t'.	Large weights. Time of 1 vibration from 360. Needle unloaded, t.	p_1, or weight of cylinder in grs.	r, or radius of cylinder in feet.	Moment of inertia $k_1 = \frac{1}{2}p_2 + r^2 \frac{t^2}{k = k_1 \frac{t^2}{t'^2 - t^2}}$	Radius of magnet in feet, or r_1.	Weight of magnet in grs., or p_1.	Moment of inertia $k_1 = \frac{1}{12}p_1 l_1^2 + \frac{1}{4}r_1^2 p_1$.
1845.															
March 7.	D 5	6″·9316	3″·7	·3033	210	·01335	3·863	9″·0289	3″·7	414	·01675	3·862	·0125	497	3·8294
May 1.	.....	6·9678	3·7202	.....	.....	.....	3·865	9·0379	3·7202	.....	.....	3·862			
March 15.	D 6	7·025	3·7266	.....	.....	.....	3·7972	9·1661	3·7266	.....	.....	3·7934	.....	490	3·7751
May 2.	.....	7·0221	3·7249	.....	.....	.....	3·7931	9·1526	3·7249	.....	.....	3·7995			
1844.															
August ...	.....	6·7881	3·6097	.....	.....	.....	3·8236	8·87276	3·6097	.....	.....	3·798			
	.....	6·7964	3·6082	.....	.....	.....	3·8056	8·8728	3·6082	.....	.....	3·7955			
	.....	6·7933	3·607	.....	.....	.....	3·8158	8·877	3·607	.....	.....	3·7842			
March 17.	A 5	5·355	2·6958	·2522	.....	.....	2·2798	7·0458	2·6958	.....	.....	2·2779	.....	418	2·232
1845.															
March 18.	A 6	6·1154	3·0733	.....	.....	.....	2·2693	8·0533	3·0733	.....	.....	2·2641	.....	416·5	2·224
19.	A 7	5·4478	2·74	.....	.....	.....	2·2742	7·18	2·74	.....	.....	2·2641	.....	416·5	2·224
22.	A 8	6·5843	3·2933	.....	.....	.....	2·2408	8·2758	3·2933	.....	.....	2·2366	.....	411·5	2·197
24.	A 9	5·657	2·81	.....	.....	.....	2·1998	7·4661	2·81	.....	.....	2·1920	.....	405·5	2·165
25.	A 10	5·7172	2·8664	.....	.....	.....	2·2551	7·5372	2·8664	.....	.....	2·2458	.....	415	2·216
26.	C 7	5·7533	4·4194	·3350	.....	.....	17·014	6·8027	4·4194	.....	.....	17·191			

The following Table contains the results of the values of $\pi^2 k$ found for each needle; the mean value of $\pi^2 k$ determined from observations prior to 1847 being considered as of value equal to those taken subsequently.

Date and Station.	Value of $\pi^2 k$ for the cylindrical magnets and the collimator magnet.					
	D 5.	A 7.	A 8.	A 9.	A 10.	C 7.
Singapore, prior to 1847	38·225	22·485	22·281	21·818	22·394	168·14
Batavia, July, 1847	38·265	22·443	22·140	21·882	22·363	167·30
Singapore, February, 1848	38·482	22·353	22·124	21·797	22·385	166·94
Singapore, December, 1848	38·423	22·296	22·126	21·783	22·307	167·25
Madras, September, 1849	38·208	22·884	21·846	21·813	22·383	

The mean value of $\pi^3 k$ has been employed in determining the value of X; that is to say, the value of $\pi^3 k$ found at a station is added to the results determined at previous periods, and a mean assumed as the true value of $\pi^3 k$.

(4.) *Value of* $P = -\frac{r^3 r_1^5 \tan a_1 - r_1^3 r^5 \tan a}{r_1^5 \tan a_1 - r^5 \tan a}$.—The value of P was determined for each needle, from the mean of many angles of deflection at the same distances. The following are the results of the mean value of P for the different magnets and the four declinometers.

March, 1846, at Singapore, the value of P for D 5 and D 6, determined by the Observatory Declinometer, was −·00309.

June, 1846, at Sarāwak, by the Induction Inclinometer,—

The value of P for	D 5	was +·00320
	D 6	+·00169
	A 6	−·024157
	A 7	−·007276
	A 8	−·00726
	A 9	−·00335
	A 10	−·00335
	C 7	−·00361

June, 1848, at Sambooanga, in the island of Mindanão, by No. III. Declinometer,— .

The value of P for	D 5	was −·00148
	A 7	−·01642
	A 8	−·00900
	A 9	−·01218
	A 10	−·01407

December, 1848, at Singapore, by No. III. Declinometer, the value of P for

A 8	was . .	−·00930
A 9	was . .	−·01059
A 10	was . .	−·00932

and by the Observatory Declinometer the value of P for A 8 was −·00751.

Remarks.—The observations of deflection are exceedingly numerous, and it is to be regretted that some of the time expended on them was not bestowed on the more complete determination of the coefficients; but, as the angles of deflection were exceedingly small, it was deemed advisable to multiply observations for the value of $\frac{m}{X}$ as much as practicable. The needle was not always vibrated on the same day on which the experiments of deflection were observed, yet care was taken that it should be vibrated at the same time at which the deflection was observed; and in low latitudes, subject to trifling disturbances, there is a greater change in a few hours on the

same day, than there will be after the lapse of some time at the same hours; thus there would be a much greater difference in the time of vibration of a needle at 11 A.M. and 5 P.M. on the same day, than if it were vibrated at 11 A.M. on different days.

The following Table contains the probable error of a single determination, and also of the mean value of the horizontal intensity, at each station in the Eastern Archipelago.

Year and Month.	Name of Station.	No. of observations.	Number of deflecting needles.	Number of instruments.	Mean value of the horizontal intensity.	Probable error	
						Of a single determination.	Of the mean value.
1845.....	Singapore	179	2	2	8·095	±·009	±·0007
March, 1846	Singapore	55	7	2	8·121	·0095	·0013
March, 1848	Singapore	199	5	2	8·116	·0090	·0006
December	Singapore	300	5	3	8·114	·0103	·0006
January, 1846 ...	Pulo Peesang	18	7	1	8·092	·0070	·0017
January	Carimons	15	6	1	8·077	·0090	·0056
February	Lingin	16	6	1	8·062	·0070	·0017
June	Sarawak	43	7	1	8·186	·007	·001
September	Batavia	56	7	1	7·894	·010	·0014
July, 1847	Batavia	218	6	1	7·891	·0084	·0006
August	Lampongs, Sumātra .	24	6	1	7·916	·0070	·0014
September	Bencoolen	24	6	1	7·913	·0053	·0011
October	Padang.....	24	6	1	7·962	·011	·002
March, 1848	Ophir, near Malacca .	20	5	1	8·255	·017	·0038
May	Pulo Labooan	20	5	1	8·240	·0052	·0012
May	Sambooanga	60	5	2	8·162	·0110	·0015
June	Keemah	60	5	2	8·253	·0120	·0015
August	Cocos	120	5	2	7·274	·010	·0009
February, 1849 ...	Nicobar	60	5	2	8·155	·011	·0014
January	Pulo Dinding	20	5	1	8·117	·006	·0014
January	Pulo Penang	20	5	1	8·159	·007	·0015
March	Hastings' Island	20	5	1	8·177	·007	·0015
April	Moulmein	59	5	2	8·119	·0085	·0011
August	Madras.....	127	5	2	8·078	·0085	·0007

Table H.

Table H, at pages cliv and clv, contains the absolute determinations of Total Force, and of the Horizontal Component, of Inclination and of Variation.

Explanation of Table H.—The first five columns require no explanation. The sixth column contains the horizontal intensity deduced from observations made with the four declinometers; the values of the horizontal intensity given by the portable declinometer, are less than those found by means of the other three declinometers; this has arisen from the shrinking of the oak deflecting bar of the portable declinometer, by which the values of r, r', &c., the distances of the deflecting from the suspended magnet, are less than they should be, consequently the angles of deflection are greater than they ought to be; $\frac{m}{X}$ is therefore greater and X less than its true value; but this shrinking must have happened before the Survey; for the ratio of the true horizontal

intensity deduced from the three declinometers, to the horizontal intensity found by means of the portable declinometer, is constant.

As the instrument was left at Madras, I have no means of measuring the true values of r, r', &c.; but if four stations be taken, Singapore at the commencement, Batavia and the Cocos during the Survey, and Madras at its termination, we find the comparison to be as follows:—

	Horizontal intensity from three declinometers.	Horizontal intensity from portable declinometer.	Ratio.
Singapore, 1845	8·0947	7·9495	1·0182
Singapore, 1846	8·121	7·951	1·0214
Singapore, 1848	8·114	7·991	1·0154
Batavia, 1847	7·897	7·784	1·0145
Cocos, 1848	7·2745	7·167	1·0150
Madras, 1849	8·0784	7·951	1·0160
		Mean ratio . . .	1·0167

by which ratio 1·0167, all the values of the horizontal intensity found by means of the portable declinometer, are multiplied for the true value.

The seventh column contains the total intensity. The total intensity has not been determined by direct observation, but from the formula $h = f \cos \delta$,

or $$f = \frac{h}{\cos \delta} = h \,.\, \sec \delta,$$

where h is the horizontal intensity,

δ the dip,

and f the total intensity.

The eighth column contains the variation or magnetic declination, found by means of the altitude and azimuth instrument and collimator magnet. The following Table is given in explanation of the manner in which the variation was determined, the station being on Direction Island at the Cocos; each observation is the mean of three sets of altitudes and azimuths, with the vertical limb in the direct and reversed positions.

Date.	Time.	Reading of the true meridian on the limb. Limb direct. 1.	2.	3.	Mean.	Limb reversed on its axis. 1.	2.	3.	Mean.	Mean of the two sets, or true meridian on the limb.	Mean of magnetic axis on the limb.	Mean magnetic variation.
												° West.
Aug. 28.	A.M.	211 18 30	211 17 10	211 18 00	211 17 53	211 34 10	211 34 40	211 34 00	211 34 17	211 26 05	210 16 28	1 09 37
29.	A.M.	211 29 47	211 29 27	211 30 17	211 29 50	211 32 23	211 30 13	211 32 57	211 31 51	211 30 50	210 18 06	1 12 44*
31.	A.M.	211 27 40	211 26 50	211 27 10	211 27 13	211 26 00	211 25 04	211 25 00	211 25 21	211 26 17	210 16 16	1 10 01
Sept. 7.	A.M.	211 23 53	211 23 23	211 25 27	211 24 14	211 30 07	211 29 53	211 29 53	211 29 58	211 27 06	210 17 06	1 10 00
9.	A.M.	211 25 30	211 25 16	211 26 20	211 25 42	211 29 40	211 27 30	211 28 03	211 28 24	211 27 03	210 17 20	1 09 43
19.	A.M.	211 28 05	211 28 14	211 30 54	211 29 04	211 23 40	211 25 40	211 23 59	211 24 26	211 26 45	210 18 37	1 08 08
27.	A.M.	212 10 17	212 10 40	212 12 44	212 11 14	212 08 30	212 07 40	212 09 47	212 08 39	212 09 50	210 55 18	1 14 38†
										Mean of the variation		1 10 42

* New spider's web, and instrument readjusted.

† New level put on the vertical limb, and position of the altitude and azimuth changed.

The eleventh column contains the altitudes of the stations above the sea level. Unfortunately, during the survey of Java, I had no barometer with me.

Table I.

Table I contains the observations made at sea; the inclination determined by Fox's Dip Circle have already been noticed. The meteorological observations, consisting of the temperature of the air and of the sea, were taken when practicable, at 15, 18, and 21 hours, at noon, and at 3, 6, and 9 P.M. The observations of the temperature of the sea were made in the following manner:—the thermometer was placed in a bucket of sea-water, allowed to stand for a few minutes whilst the other instruments were observed, and the thermometer was read off whilst its bulb was still immersed.

The Table contained at pages clvi and clvii requires no explanation.

On the Direction of the Isoclinal and Isodynamic Lines, and the Lines of Equal Variation or Magnetic Declination.

On the Isoclinal Lines.—The observations of dip or inclination have been combined for the position of the isoclinal lines, their mean direction, and their mean distance apart; they have been formed into four different groups.

1st Group.—Singapore, Borneo, and Java, afford forty stations; and if we call δ the dip at the central position, u the angle which the isoclinal line passing through the central position makes with the meridian, and r a constant coefficient, which determines the rate of increase in a direction perpendicular to the isoclinal line; and we put

$$r \cos u = x$$
$$r \sin u = y,$$

we may make equations of condition of the following form:

$$ax + by = \delta - \delta',$$

where a and b are coordinates of distance in longitude and latitude of the several stations from the mean, expressed in geographical miles; δ' the inclination at these several stations, and δ the mean dip.

Then from this group we obtain, the results alone being given,

At a mean latitude . = 6° 17′ South.
Mean longitude = 108 55 East.
And mean dip . . = − 27 01·5 South.
$x = -0'{\cdot}132$ $y = +1'{\cdot}935$
$r = +1'{\cdot}940$ and $u = -86°\ 06'$.

The axes of coordinates are throughout assumed positive when taken to the north and west; so that as we proceed to the north, the dip increases at the rate of 1′·940 perpendicular to the isoclinal line which forms an angle of N. 86° 06′ E. to S. 86° 06′ West.

2nd Group.—Sumātra contains thirty stations; the resulting equations give—

At a mean latitude . = 0° 08′ South.
At a mean longitude. =100 31 East.
And mean dip . . = 16 36′·6 South.
$x=+0\cdot230$; $y=+2\cdot008$
$r=+2'\cdot021$ and $u=83°\ 28'$.

We have therefore, the isoclinal line in Sumātra forming an angle of N. 83° 28′ W. to S. 83° 28′ East, and the line at right angles to it increasing at the rate of 2′·021; and as the central station, through which this line passes, is only 8 miles to the south of the equator, we may assume this to be the rate at which the dip increases at nearly right angles to the terrestrial equator in longitude 100° 31′ East.

3rd Group.—From the third group we have thirty observations taken at sea.

The resulting equations give—

At a mean latitude . = 2° 38′ North.
At a mean longitude =110 05 East.
And mean dip . . . = 9 11′·7 South.
$x=+0\cdot089$; $y=+1\cdot991$
$u=87°\ 26'$; $r=+1'\cdot993$.

We have, therefore, the isoclinal line running N. 87° 26′ W. to S. 87° 26′ East, and the line at right angles increasing at the rate of +1′·993 for each geographical mile.

4th Group.—In the fourth group are contained the principal stations in the Magnetic Survey, extending from the 80th to the 125th degree of east longitude, and from 16½° North to 12° South.

From the resulting equations we obtain—

At a mean latitude . = 0° 09′ North.
At a mean longitude =104 44 East.
And mean dip . . = 14 40′·4 South.
$x=+0\cdot114$ $y=+1'\cdot947$
$u=86°\ 39'$; $r=+1'\cdot953$.

The isoclinal line runs therefore N. 86° 39′ W. to S. 86° 39′ East, and the line at right angles to it increases at the rate of 1′·953 for each geographical mile.

On the Lines of Equal Horizontal Intensity.

For the lines of equal horizontal intensity the equations of condition have been combined in the same manner by the method of least squares.

From one group of forty stations

At a mean latitude of . . . . 0° 38′·5 North.
At a mean longitude of . . . . 102 26 East.
$x=+\cdot000312076$; $y=+\cdot000765277$
$r=+\cdot0008249$; $u=67°\ 48'$.

The line of equal horizontal intensity forms an angle of N. 67° 48′ W. to S. 67° 48′ E. with the meridian, and on the line perpendicular to this the horizontal intensity increases at the rate of ·0008249 the geographical mile.

From a second group of seventy-seven stations, comprising all those at some distance to the south of the line of maximum horizontal intensity, we obtain

$$\begin{aligned} &\text{At a mean latitude} \quad . \quad . \quad . \quad . = 3^\circ\ 40' \text{ South.} \\ &\text{At a mean longitude} \quad . \quad . \quad . \quad . = 106\ 33{\cdot}0 \text{ East.} \end{aligned}$$

$$x = +{\cdot}00028453; \quad y = +{\cdot}0005117$$
$$u = 60^\circ\ 57'; \quad r = +{\cdot}000585439.$$

The line of equal horizontal intensity forms an angle of N. 60° 57′ W. to S. 60° 57′ E. with the meridian, and the horizontal intensity on a line perpendicular to this increases at the rate of ·0005855 the geographical mile.

Lines of Total Intensity.

The total intensity has been determined by the formula $h = f \cos \delta$,

or $$f = \frac{h}{\cos \delta} = h \sec \delta,$$

where h is the horizontal intensity,

δ the dip,

f the total intensity;

eighty equations of condition of the following form,

$$ax + by = f - f',$$

have been combined by the method of least squares, so as to assume the form of the two following equations:—

$$a^2x + aby = a(f - f')$$
$$abx + b^2y = b(f - f'),$$

a and b being the coordinates of distance in longitude and latitude from the mean station for any station, and f' its intensity; f the mean total intensity $= 8{\cdot}745$.

Then by adding together the equations of condition for each station, we obtain the following:—

$$r = -{\cdot}001073,$$
$$u = 85^\circ\ 36',$$

at a mean latitude of 3° 05′ S. and a mean longitude of 106° 47′ E.

The angle which the line of equal total intensity forms with the meridian is N. 85° 36′ W. to S. 85° 36′ E., and increases southerly at the rate of ·001073 the geographical mile. The line of least intensity in that part of the Archipelago over which I have carried the Survey, agrees nearly with the line of no dip. On looking over the list of stations, we find Sambooanga, Nicobar, and Madras, with the least total inten-

sity. Sambooanga and Nicobar are about forty miles north of the line of no dip. The angle which the line of least intensity makes with the meridian is nearly a right angle.

Lines of Variation.

The first attempt which I made to determine the lines of equal variation was unsatisfactory. From 120 equations of condition combined by the method of least squares, I obtained results quite at variance with the actual fact.

I then broke up the observations into three groups, one to the extreme west, comprising the observations taken in Sumātra, one in the centre comprising the observations taken in Java, and the third group to the east. The results thus obtained are more satisfactory, for the line of equal variation in the longitudes and latitudes over which the Survey extended is a straight line for a very short distance only.

1st, or Eastern group:—

At a mean latitude	= 2° 03′ North.
At a mean longitude	=113 53 East.
And mean variation	= 1 23 East.

The line of equal variation forms an angle of N. 52° 51′ E. to S. 52° 51′ W. with the meridian, and the rate of progression, or the value of r, is $-0'{\cdot}0346$ the geographical mile.

2nd, or Sumātra group:—

At a mean latitude	= 1° 36′ North.
At a mean longitude	=100 36 East.
At a mean variation	= 1 35 East.

$$u = -82° 06',$$
$$\text{and } r = +'0545;$$

so that the variation increases as we proceed northerly, at the rate of $+'0545$ the geographical mile; the line of equal variation forming an angle of N. 82° 06′ E. to S. 82° 06′ W.

3rd, or Java group:—

At a mean latitude	= 7° 03′ South.
At a mean longitude	=108 51 East.
At a mean variation	=+0 35 East.

The value of $r = 0'{\cdot}145$.
The value of $u = -89° 24'$,

so that the line of equal variation in Java forms with the meridian an angle of N. 89° 24′ E., and proceeds at the rate of $0'{\cdot}145$ the geographical mile.

The lines have been laid down on the charts nearly in accordance with the foregoing results.

The line of equal inclination forms an angle of 86° 40′ with the meridian, and changes in a direction perpendicular to it at the rate of 1′·970 the geographical mile.

The line of equal horizontal intensity forms an angle of nearly 65° with the meridian. For the position of the central line of maximum horizontal intensity, I have taken stations north and south of this line having the same horizontal intensity, and have divided the distance between them; and in laying down the rate of decrease of the horizontal intensity, I have fixed upon the Java group, which has the greatest number of stations, as decreasing at the rate given me by the equations of condition; but since the horizontal intensity at the Cocos shows a much more rapid decrease when at some distance from the line of maximum horizontal intensity, I have gradually increased the rate of progression to the Cocos, and decreased it in the same proportion northwards from Java to the line of maximum horizontal intensity.

The lines of total intensity are laid down in strict conformity with the resulting equations of condition. The direction of the lines is between 85° and 86°, and proceeds at the rate of ·001073 the geographical mile. There is much less difficulty in laying down the total intensity lines than the lines of horizontal intensity; for the former, and the rate of progression in a direction normal to them, are functions of the dip and horizontal intensity; and since the dip changes very rapidly, whilst the horizontal intensity is nearly stationary in the immediate vicinity of the maximum horizontal intensity, it follows, first, that the line of minimum total intensity will coincide nearly with the line of no dip; and secondly, that its rate of progression, or the value of r, will be as uniform and as constant as the lines of dip, for it has been shown that over the space of 28° of latitude over which this Survey extends, the dip changes at the rate of nearly two miles for every mile of latitude.

In laying down the lines of variation, I have been guided partly by the equations of condition, but to be directed by these alone would lead to very unsatisfactory results. I have, in the Java group and in the Eastern group, conformed to the results of the equations of condition combined by the method of least squares, whilst in the western group I have simply connected together by lines the stations having the same variation.

Explanation of Plates XII. *and* XIII.

Plate XII. contains the isoclinal lines or lines of equal magnetic dip and lines of equal magnetic declination, as well as the central lines of minimum total intensity and of maximum horizontal intensity.

Plate XIII. contains the isodynamic lines or lines of equal horizontal intensity and of equal total intensity; and in addition, the line of no magnetic declination and the line of no dip.

Pimlico Lodge, Westminster,
November 15, 1850.

ERRATA.

Page ii, line 1, *omit* Moulmein.

—— iv, line 18, at 21 hours, *for* 1·1 *read* 0·1.

—— iv, line 22, at 21 hours, *for* 2·1 *read* 1·1.

—— iv, line 23, at 21 hours, *for* 0·52 *read* 0·27.

—— iv, line 24, in the line of Oscillation, *for* 1·33, 1·28, &c., and

—— ii, line 15, in the line of Batavia, Spring, *for* 1·33, 1·28, &c. *read*

1·48, 1·43, 1·38, 1·55, 1·40, 0·58, 0·00, 0·15, 0·38, 0·80, 1·28, 1·78, 2·21, 2·25, 1·95, 1·60, 1·35, 1·08, 0·73.....1·25.

—— vi, line 11, at 21 hours, *for* 1·2 *read* 0·2.

—— vi, line 15, at 21 hours, *for* 1·9 *read* 0·9.

—— vi, line 16, at 21 hours, *for* 0·47 *read* 0·22.

—— vi, line 17, in the line of Oscillation, *for* 1·50, 1·46, &c., and

—— ii, line 33, in the line of Batavia, Spring, *for* 1·50, 1·46, &c. *read*

1·60, 1·56, 1·40, 1·50, 1·38, 0·48, 0·00, 0·10, 0·60, 1·23, 1·93, 2·58, 3·13, 3·28, 3·06, 2·60, 2·36, 1·98, 1·50.....1·68.

—— x and xi, line 1, *for* the sign (') *read* scale divisions.

—— xi, last line but one at 21 hours, *for* 1·1 *read* 0·1.

Abstracts and Tables of the Magnetic and Meteorological Instruments at Sixteen Stations in the Indian Archipelago.

Oscillation of the Declination at various Stations

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Moulmein.											
Madras	.....	.....	.....	1·85	1·87	1·94	2·59	3·75	4·12	3·11	2·02
Nicobar	.....	.....	.....	1·68	1·44	0·92	0·18	0·00	0·42	2·02	3·38
Sambooanga	.....	.....	.....	3·01	3·06	3·10	3·58	3·91	3·28	2·01	0·85
Penang	.....	.....	.....	2·02	2·00	1·64	0·66	0·00	0·70	2·34	4·00
Pulo Dinding	.....	.....	.....	3·70	3·37	3·07	2·40	0·67	0·00	1·53	4·20
Sarawak	1·00	1·13	1·34	1·54	1·67	1·84	2·41	3·22	2·67	1·56	0·92
Keemah	.....	.....	.....	3·26	3·11	3·31	3·33	4·56	3·88	2·46	1·33
Pulo Peesang	.....	.....	.....	.....	.....	1·51	1·00	0·20	0·00	0·92	1·32
Singapore	.....	.....	.....	2·36	2·02	1·66	0·77	0·00	0·15	1·10	2·21
Carimon	.....	.....	.....	.....	.....	1·60	0·68	0·00	0·45	1·56	2·60
Bowaya	.....	.....	.....	.....	.....	1·80	0·25	0·00	0·47	1·17	2·15
Padang	.....	.....	.....	1·91	1·83	1·62	1·05	0·27	0·00	0·17	0·45
Bencoolen	.....	.....	.....	2·14	2·24	2·42	3·02	3·34	1·78	0·52	0·14
Batavia, Winter	2·28	2·20	2·15	2·33	2·28	2·10	1·55	0·48	0·00	0·13	0·75
Batavia, Spring	.....	.....	.....	1·33	1·28	1·23	1·40	1·25	0·43	0·10	0·00
Cocos	.....	.....	.....	3·28	3·44	3·41	3·81	3·36	1·75	0·39	0·00

Declino-

Moulmein	.....	.....	.....	1·6	1·0	0·7	1·5	2·2	2·0	2·4	1·7
Madras	.....	.....	.....	0·81	0·81	0·94	1·80	2·90	3·29	2·54	1·64
Nicobar	.....	.....	.....	1·44	1·24	0·88	0·08	0·00	0·38	2·19	2·96
Sambooanga	.....	.....	.....	3·22	3·27	3·23	3·75	3·57	2·34	1·78	1·07
Penang	.....	.....	.....	2·26	2·28	1·88	0·88	0·00	0·68	2·32	3·34
Pulo Dinding	.....	.....	.....	4·07	3·60	3·34	2·54	0·80	0·00	1·70	4·47
Sarawak	0·84	0·92	1·37	1·22	1·26	1·39	1·88	2·57	2·09	1·00	0·37
Keemah	.....	.....	.....	2·01	1·78	2·02	2·22	2·80	2·39	1·20	0·43
Pulo Peesang	.....	.....	.....	.....	1·00	1·75	1·06	0·00	0·18	1·02	1·26
Singapore	.....	.....	.....	2·64	2·37	2·01	1·15	0·09	0·00	1·08	2·35
Carimon	.....	.....	.....	.....	.....	1·92	0·55	0·00	0·92	2·18	3·47
Bowaya	.....	.....	.....	.....	.....	2·07	0·45	0·00	0·15	1·20	2·40
Padang	.....	.....	.....	1·91	1·82	1·58	1·03	0·18	0·00	0·35	0·98
Bencoolen	.....	.....	.....	2·15	2·50	3·10	4·10	3·40	2·35	1·05	0·30
Batavia, Winter	3·25	3·10	2·95	2·65	2·55	2·35	1·75	0·60	0.00	0·20	0·95
Batavia, Spring	.....	.....	.....	1·50	1·46	1·30	1·40	1·28	0·38	0·15	0·00
Cocos	.....	.....	.....	2·70	2·82	2·73	3·13	2·63	1·08	0·00	0·15

Declino-

Moulmein	.....	.....	.....	2·3	1·6	1·4	2·0	2·9	3·2	3·2	2·6
Madras	.....	.....	.....	2·01	2·11	2·15	2·99	4·43	4·60	3·47	2·10
Nicobar	.....	.....	.....	1·26	1·12	0·70	0·00	0·02	0·80	2·18	3·54
Sambooanga.											
Penang	.....	.....	.....	1·94	2·16	1·60	0·44	0·00	0·54	2·46	3·62
Pulo Dinding	.....	.....	.....	3·07	2·87	2·67	1·67	0·27	0·00	1·84	4·70
Sarawak.											
Keemah	.....	.....	.....	1·68	1·51	1·67	1·73	2·57	1·87	0·87	0·18
Pulo Peesang.											
Singapore	.....	.....	.....	2·34	2·02	1·62	0·74	0·00	0·08	1·08	2·22
Singapore, No. IV.	.....	.....	.....	2·50	2·76	2·29	1·44	0·13	0·00	0·90	1·99
Singapore, No. V.	.....	.....	.....	2·04	1·83	1·54	0·59	0·00	0·02	0·98	1·99
Padang.											
Bencoolen											
Batavia, Winter.											
Batavia, Spring.											
Cocos	.....	.....	.....	2·90	3·00	2·97	3·36	2·89	1·30	0·13	0·00

in the Eastern Archipelago.—Declinometer No. I.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
′	′	′	′	′	′	′	′	′	′	′	′	′	′
0·84	0·00	0·10	0·97	1·85	2·72	2·80	2·47	2·21	2·02	1·96	.....	.....	2·06
4·12	4·26	4·52	4·74	4·38	4·00	3·56	2·78	3·06	2·90	2·74	.....	.....	2·68
0·65	0·00	0·16	0·38	0·56	1·23	1·90	2·00	2·08	1·86	1·76	.....	.....	1·86
3·98	4·90	4·86	4·54	4·18	3·82	2·90	2·40	2·62	2·72	2·58	.....	.....	2·78
5·67	6·83	7·23	7·47	7·40	6·63	5·80	5·13	5·30	4·93	4·60	.....	.....	4·52
0·23	0·00	0·03	0·29	0·61	1·06	1·23	0·93	0·92	0·79	0·87	0·85	0·83	0·86
0·42	0·00	0·53	1·31	1·74	2·12	2·23	2·22	2·36	2·24	2·16	.....	.....	2·28
2·56	3·92	4·54	4·40	3·68	3·42	3·24	3·36	3·20	2·77	2·14	.....	.....	2·44
3·30	4·21	5·11	4·96	4·75	4·18	3·55	3·30	3·31	3·04	2·97	.....	.....	2·77
3·15	3·35	3·21	2·80	1·95	1·36	1·10	1·33	1·58	1·80	.....	.....	.....	1·78
3·17	3·72	3·52	2·97	2·45	2·40	2·32	2·47	2·32	2·20	.....	.....	.....	2·09
1·26	2·43	3·05	3·24	3·24	3·13	2·66	2·35	2·46	2·18	1·85	.....	.....	1·85
0·00	0·38	1·18	2·06	3·20	3·48	2·40	1·80	1·54	1·32	0·98	.....	.....	1·79
1·75	3·13	4·33	4·68	4·53	4·05	3·48	3·10	3·08	2·88	2·61	2·15	2·11	2·43
0·23	0·65	1·13	1·63	2·06	2·10	1·80	1·45	1·20	0·93	0·58	.....	.....	1·10
0·38	1·44	2·69	3·72	4·26	4·32	3·78	3·22	3·30	2·99	2·97	.....	.....	2·76

meter No. II.

0·8	0·00	0·00	0·4	1·1	1·9	2·3	2·3	1·9	1·4	1·3	.....	.....	1·4
0·69	0·00	0·25	0·89	1·68	2·13	1·91	1·34	1·00	0·67	0·53	.....	.....	1·34
3·72	3·78	3·98	4·10	3·70	3·24	2·80	1·92	2·30	2·24	2·12	.....	.....	2·27
1·08	0·00	0·15	0·65	0·77	1·60	2·17	2·17	2·15	1·95	1·98	.....	.....	1·94
3·10	4·24	4·16	3·82	3·44	3·02	2·20	1·24	1·88	1·84	1·66	.....	.....	2·42
5·84	6·44	6·84	7·40	7·44	6·80	5·94	5·07	5·20	4·64	4·37	.....	.....	4·55
0·13	0·00	0·19	0·67	1·24	1·76	1·96	1·52	1·21	0·97	1·05	0·98	0·83	1·14
0·11	0·00	0·70	1·19	1·46	1·69	1·75	1·59	1·54	1·44	1·13	.....	.....	1·45
1·76	2·46	3·26	3·08	2·38	2·22	2·15	1·96	1·96	1·78	1·73	.....	.....	1·72
3·58	4·50	5·53	5·43	5·18	4·63	4·00	3·71	3·64	3·41	3·06	.....	.....	3·07
4·23	4·67	4·60	4·37	3·68	3·25	2·83	2·95	2·88	2·60	.....	.....	.....	2·83
3·35	3·78	3·63	3·33	2·85	2·83	2·78	2·80	2·75	2·23	.....	.....	.....	2·29
2·09	3·56	4·49	4·82	4·80	4·38	3·72	3·23	3·15	2·63	2·28	.....	.....	2·47
0·00	0·35	1·45	3·10	4·30	4·25	4·00	4·15	3·95	3·70	3·05	.....	.....	2·69
2·10	3·90	5·12	5·70	5·67	5·25	4·63	4·17	4·05	3·90	3·60	3·22	3·07	3·10
0·50	1·13	1·83	2·48	3·03	3·18	2·96	2·50	2·26	1·88	1·40	.....	.....	1·58
0·89	2·17	3·33	4·33	4·72	4·55	3·91	3·10	2·71	2·60	2·29	.....	.....	2·62

meter No. III.

1·4	0·2	0·00	0·5	1·5	2·7	3·3	2·9	2·2	1·6	1·4	.....	.....	1·9
0·87	0·00	0·05	0·70	1·68	2·39	2·43	1·86	1·62	1·45	1·43	.....	.....	2·02
4·00	4·10	4·22	4·22	3·96	3·50	3·06	2·37	2·67	2·59	2·49	.....	.....	2·46
4·16	5·28	5·62	5·04	4·82	4·52	3·86	3·44	3·62	3·72	3·40	.....	.....	3·17
6·17	7·14	7·74	7·97	7·74	6·70	5·60	4·54	4·57	4·14	3·80	.....	.....	4·38
0·00	0·06	0·82	1·58	2·01	2·30	2·31	2·17	2·04	1·76	1·45	.....	.....	1·52
3·36	4·26	5·15	5·00	4·77	4·23	3·59	3·29	3·30	2·97	2·60	.....	.....	2·77
3·02	3·99	4·97	4·89	4·72	4·25	3·77	3·57	3·38	3·09	3·16	.....	.....	2·89
2·94	3·90	4·88	4·75	4·48	4·08	3·40	3·17	3·12	2·89	2·62	.....	.....	2·59
0·73	2·06	3·46	4·47	5·01	5·01	4·40	3·61	3·57	3·15	2·84	.....	.....	2·89

Oscillation of Declination at Singa-

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	′	′	′	′	′	′	′	′	′	′	′
November .....1848...	.....	.....	.....	2·27	3·02	2·40	1·52	0·16	0·00	0·85	1·96
December	.....	.....	.....	2·74	2·50	2·19	1·36	0·10	0·00	0·96	2·02
Sums	.....	.....	.....	5·01	5·52	4·59	2·88	0·26	0·00	1·81	3·98
Means	.....	.....	.....	2·50	2·76	2·29	1·44	0·13	0·00	0·90	1·99
Oscillation	.....	.....	.....	2·50	2·76	2·29	1·44	0·13	0·00	0·90	1·99

No.

November .....1848...	... ..	.....	.....	2·20	1·99	1·66	0·76	0·38	0·00	1·14	2·24
December	.....	.....	.....	2·26	2·05	1·80	0·80	0·00	0·43	1·21	2·12
Sums	.....	.....	.....	4·46	4·04	3·46	1·56	0·38	0·43	2·35	4·36
Means	.....	.....	.....	2·23	2·02	1·73	0·78	0·19	0·21	1·17	2·18
Oscillation	.....	.....	.....	2·04	1·83	1·54	0·59	0·00	0·02	0·98	1·99

Oscillation of the Declination at Batavia in Java,

November .....1846...	2·3	1·9	2·0	1·8	1·7	1·7	0·8	0·2	0·0	0·4	1·1
December	2·6	2·5	2·5	2·3	2·2	1·8	1·1	0·1	0·0	0·4	1·4
January .....1847...	2·2	2·3	2·1	2·6	2·5	2·2	1·7	0·3	0·0	0·4	0·9
February	2·7	2·8	2·7	3·3	3·4	3·4	3·3	2·0	0·7	0·0	0·3
Sums	9·8	9·5	9·3	10·0	9·8	9·1	6·9	2·6	0·7	1·2	3·7
Means	2·45	2·37	2·32	2·50	2·45	2·27	1·72	0·65	0·17	0·30	0·92
Oscillation	2·28	2·20	2·15	2·33	2·28	2·10	1·55	0·48	0·00	0·13	0·75

Oscillation of the Declination at Batavia in Java,

March .....1847...	.....	.....	.....	1·8	1·6	1·4	1·3	0·7	0·0	1·1	0·7
April	.....	.....	.....	2·7	2·6	2·4	2·5	1·9	0·9	0·0	0·4
May	.....	.....	.....	1·6	1·6	1·7	2·1	2·1	1·2	0·4	0·0
June	.....	.....	.....	0·9	1·0	1·1	1·4	2·0	1·3	0·6	0·6
Sums	.....	.....	.....	7·0	6·8	6·6	7·3	6·7	3·4	2·1	1·7
Means	.....	.....	.....	1·75	1·70	1·65	1·82	1·67	0·85	0·52	0·42
Oscillation	.....	.....	.....	1·33	1·28	1·23	1·40	1·25	0·43	0·10	0·00

Oscillation of the Declination at Sarawak in Borneo,

June .....1846...	1·17	1·38	1·61	1·79	1·83	2·02	2·52	3·24	2·70	1·73	0·96
July	0·80	0·93	1·24	1·42	1·63	1·77	2·27	2·92	2·36	1·43	0·75
August	1·18	1·22	1·33	1·55	1·70	1·88	2·58	3·64	3·09	1·67	1·19
Sums	3·15	3·53	4·18	4·76	5·16	5·67	7·37	9·80	8·15	4·83	2·90
Means	1·05	1·18	1·39	1·59	1·72	1·89	2·46	3·27	2·72	1·61	0·97
Oscillation	1·00	1·13	1·34	1·54	1·67	1·84	2·41	3·22	2·67	1·56	0·92

Oscillation of the Declination at Padang in Sumatra,

October .....1847..	.....	.....	.....	1·61	1·53	1·55	1·43	1·12	0·68	0·48	0·00
November	.....	.....	.....	1·82	1·84	1·54	0·83	0·00	0·13	0·18	0·69
December	.....	.....	.....	2·78	2·69	2·36	1·67	0·61	0·00	0·46	1·16
January .....1848...	.....	.....	.....	2·22	2·07	1·85	1·08	0·17	0·00	0·37	0·76
Sums	.....	.....	.....	8·43	8·13	7·30	5·01	1·90	0·81	1·49	2·51
Means	.....	.....	.....	2·11	2·03	1·82	1·25	0·47	0·20	0·37	0·65
Oscillation	.....	.....	.....	1·91	1·83	1·62	1·05	0·27	0·00	0·17	0·45

pore, Eastern Archipelago.—No. IV.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
3·12	3·95	5·04	4·87	5·07	4·41	3·96	3·96	3·40	3·00	2·58	.....	.....	2·98
2·93	4·04	4·90	4·92	4·37	4·09	3·59	3·19	3·36	3·19	3·74	.....	.....	2·80
6·05	7·99	9·94	9·79	9·44	8·50	7·55	7·15	6·76	6·19	6·32	.....	.....	5·78
3·02	3·99	4·97	4·89	4·72	4·25	3·77	3·57	3·38	3·09	3·16	.....	.....	2·89
3·02	3·99	4·97	4·89	4·72	4·25	3·77	3·57	3·38	3·09	3·16	.....	.....	2·89

V.

3·29	4·27	5·31	4·99	4·96	4·59	3·88	3·89	3·72	3·41	3·14	.....	.....	2·94
2·97	3·92	4·83	4·89	4·39	3·95	3·31	2·83	2·90	2·75	2·49	.....	.....	2·63
6·26	8·19	10·14	9·88	9·35	8·54	7·19	6·72	6·62	6·16	5·63	.....	.....	5·57
3·13	4·09	5·07	4·94	4·67	4·27	3·59	3·36	3·31	3·08	2·81	.....	.....	2·78
2·94	3·90	4·88	4·75	4·48	4·08	3·40	3·17	3·12	2·89	2·62	.....	.....	2·59

Eastern Archipelago.—Declinometer No. I.

2·2	3·3	4·6	4·6	4·3	3·9	3·6	3·0	2·9	2·6	2·5	2·2	2·2	2·3
2·2	3·4	4·2	4·4	4·2	3·9	3·3	2·9	2·9	2·8	2·7	2·5	2·3	2·5
1·8	3·2	4·3	4·5	4·3	3·6	3·1	3·0	3·1	2·9	2·2	2·0	2·0	2·4
1·5	3·3	4·9	5·9	6·0	5·5	4·6	4·2	4·1	3·9	3·7	2·5	2·6	3·3
7·7	13·2	18·0	19·4	18·8	16·9	14·6	13·1	13·0	12·2	11·1	9·2	9·1	10·5
1·92	3·30	4·50	4·85	4·70	4·22	3·65	3·27	3·25	3·05	2·78	2·30	2·28	2·62
1·75	3·13	4·33	4·68	4·53	4·05	3·48	3·10	3·08	2·88	2·61	2·15	2·11	2·43

Eastern Archipelago.—Declinometer No. I.

1·4	2·1	2·5	2·8	2·7	2·6	2·3	2·2	2·1	1·9	1·3	.....	.....	1·7
1·2	2·0	2·6	3·0	3·3	3·1	3·0	2·9	2·6	2·3	2·1	.....	.....	2·2
0·0	0·1	0·7	1·5	2·2	2·6	2·3	1·7	1·3	0·9	0·6	.....	.....	1·3
0·0	0·1	0·4	0·9	1·7	1·8	1·3	0·7	0·5	0·3	0·0	.....	.....	0·9
2·6	4·3	6·2	8·2	9·9	10·1	8·9	7·5	6·5	5·4	4·0	.....	.....	6·1
0·65	1·07	1·55	2·05	2·48	2·52	2·22	1·87	1·62	1·35	1·00	.....	.....	1·52
0·23	0·63	1·13	1·63	2·06	2·10	1·80	1·45	1·20	0·93	0·58	.....	.....	1·10

Eastern Archipelago.—Declinometer No. I.

0·42	0·08	0·00	0·27	0·53	0·87	0·91	0·71	0·85	0·72	0·81	0·87	0·92	1·20
0·29	0·08	0·00	0·11	0·43	0·79	1·08	0·78	0·64	0·54	0·52	0·55	0·59	1·00
0·13	0·00	0·23	0·65	1·02	1·67	1·86	1·46	1·42	1·27	1·42	1·28	1·14	1·42
0·84	0·16	0·23	1·03	1·98	3·33	3·85	2·95	2·91	2·53	2·75	2·70	2·65	3·62
0·28	0·05	0·08	0·34	0·66	1·11	1·28	0·98	0·97	0·84	0·92	0·90	0·88	0·91
0·23	0·00	0·03	0·29	0·61	1·06	1·23	0·93	0·92	0·79	0·87	0·85	0·83	0·86

Eastern Archipelago.—Declinometer No. I.

0·78	2·12	2·91	3·13	2 90	2·83	2·43	2·28	2·03	1·78	1·33	.....	.....	1·73
1·83	2·79	3·34	3·45	3·18	2·93	2·55	2·36	2·36	2·08	1·81	.....	.....	1·88
1·97	3·18	3·75	3·95	4·25	4·16	3·69	3·04	3·15	3·10	2·85	.....	.....	2·57
1·25	2·42	3·00	3·24	3·45	3·39	2·79	2·52	3·12	2·55	2·22	.....	.....	8·02
5·83	10·51	13·00	13·77	13·78	13·31	11·46	10·20	10·66	9·51	8·21	.....	.....	8·20
1·46	2·63	3·25	3·44	3·44	3·33	2·86	2·55	2·66	2·38	2·05	.....	.....	2·05
1·26	2·43	3·05	3·24	3·24	3·13	2·66	2·35	2·46	2·18	1·85	.....	.....	1·85

Oscillation of the Declination at Singapore,

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	′	′	′	′	′	′	′	′	′	′	′
November .....1848....	.....	.....	.....	2·33	1·94	1·53	0·70	0·00	0·10	0·93	2·16
December	.....	.....	.....	2·38	2·11	1·79	0·85	0·00	0·21	1·28	2·27
Means	.....	.....	.....	2·36	2·02	1·66	0·77	0·00	0·15	1·10	2·21

Oscillation of the Declination at Batavia in

November ...1846.....	2·4	2·2	2·1	1·9	1·8	1·7	0·9	0·1	0·0	0·4	1·2
December	3·2	3·0	2·9	2·7	2·4	2·1	1·3	0·3	0·0	0·5	1·5
January .....1847.....	3·7	3·7	3·6	2·9	2·7	2·4	1·8	0·4	0·0	0·5	1·2
February	3·9	4·1	3·8	3·7	3·8	3·7	3·5	2·2	0·6	0·0	0·5
Sums	13·2	13·0	12·4	11·2	10·7	9·9	7·5	3·0	0·6	1·4	4·4
Means	3·40	3·25	3·10	2·80	2·70	2·50	1·90	0·75	0·15	0·35	1·10
Oscillation	3·25	3·10	2·95	2·65	2·55	2·35	1·75	0·60	0·00	0·20	0·95

Oscillation of the Declination at Batavia in

March .....1847.....	.....	.....	.....	2·3	2·1	1·7	1·5	0·9	0·0	1·2	0·8
April	.....	.....	.....	2·8	2·7	2·5	2·4	2·0	0·8	0·0	0·5
May	.....	.....	.....	1·6	1·6	1·6	2·0	1·9	1·1	0·4	0·0
June	.....	.....	.....	0·6	0·7	0·7	1·0	1·6	0·9	0·3	0·0
Sums	.....	.....	.....	7·3	7·1	6·5	6·9	6·4	2·8	1·9	1·3
Means	.....	.....	.....	1·82	1·78	1·62	1·72	1·60	0·70	0·47	0·32
Oscillation	.....	.....	.....	1·50	1·46	1·30	1·40	1·28	0·38	0·15	0·00

Oscillation of the Declinometer No. III.

November ...1848.....	.....	.....	.....	2·32	1·92	1·48	0·64	0·09	0·00	0·94	2·16
December	.....	.....	.....	2·45	2·20	1·84	0·93	0·00	0·25	1·30	2·36
Means	.....	.....	.....	2·38	2·06	1·66	0·78	0·04	0·12	1·12	2·26
Oscillation	.....	.....	.....	2·34	2·02	1·62	0·74	0·00	0·08	1·08	2·22

Oscillation of the Declination at Sarawak in

June .....1846.....	0·65	0·84	1·03	1·14	1·14	1·28	1·76	2·45	1·86	1·00	0·41
July	1·19	1·23	2·23	1·58	1·64	1·61	1·89	2·42	2·00	0·86	0·19
August	0·68	0·69	0·85	0·94	1·01	1·29	1·98	2·85	2·40	1·15	0·51
Sums	2·52	2·76	4·11	3·66	3·79	4·18	5·63	7·72	6·26	3·01	1·11
Means	0·84	0·92	1·37	1·22	1·26	1·39	1·88	2·57	2·09	1·00	0·37
Oscillation	0·84	0·92	1·37	1·22	1·26	1·39	1·88	2·57	2·09	1·00	0·37

Oscillation of the Declination at Padang in Sumatra,

October .....1847.....	.....	.....	.....	1·21	1·15	1·12	0·98	0·61	0·22	0·03	0·00
November	.....	.....	.....	1·98	1·94	1·64	0·94	0·00	0·16	0·29	1·06
December	.....	.....	.....	2·66	2·59	2·26	1·65	0·43	0·00	0·71	1·81
January .....1848.....	.....	.....	.....	2·15	1·97	1·67	0·92	0·05	0·00	0·75	1·41
Sums	.....	.....	.....	8·00	7·65	6·69	4·49	1·09	0·38	1·78	4·28
Means	.....	.....	.....	2·00	1·91	1·67	1·12	0·27	0·09	0·44	1·07
Oscillation	.....	.....	.....	1·91	1·82	1·58	1·03	0·18	0·00	0·35	0·98

Eastern Archipelago.—Declinometer No. I.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
3·47	4·24	5·22	5·02	5·07	4·35	3·76	3·74	3·60	3·33	2·94	.....	.....	2·86
3·12	4·19	5·01	4·90	4·42	4·02	3·33	2·85	3·03	2·75	3·01	.....	.....	2·68
3·30	4·21	5·11	4·96	4·75	4·18	3·55	3·30	3·31	3·04	2·97	.....	.....	2·77

Java, Eastern Archipelago.—Declinometer No. II.

2·4	3·9	4·8	5·2	5·0	4·6	4·0	3·4	3·2	2·8	2·6	2·3	2·3	2·5
2·5	4·2	5·3	5·7	5·6	5·4	4·9	4·3	4·2	3·9	3·5	3·2	2·8	3·3
2·0	4·0	5·1	5·5	5·5	4·9	4·4	4·2	4·2	4·5	4·2	3·8	3·6	3·2
2·1	4·1	5·9	7·0	7·2	6·7	5·8	5·4	5·2	5·0	4·7	4·2	4·2	4·0
9·0	16·2	21·1	23·4	23·3	21·6	19·1	17·3	16·8	16·2	15·0	13·5	12·9	13·0
2·25	4·05	5·27	5·85	5·82	5·40	4·78	4·32	4·20	4·05	3·75	3·37	3·22	3·25
2·10	3·90	5·12	5·70	5·67	5·25	4·63	4·17	4·05	3·90	3·60	3·22	3·07	3·10

Java, Eastern Archipelago.—Declinometer No. II.

1·8	2·7	3·3	3·7	3·7	3·7	3·6	3·4	3·3	3·0	2·2	.....	.....	2·3
1·3	2·3	3·1	3·7	4·1	4·0	3·9	3·8	3·4	3·1	2·7	.....	.....	2·5
0·1	0·5	1·3	2·1	3·0	3·4	3·1	2·4	2·0	1·5	1·1	.....	.....	1·6
0·1	0·3	0·9	1·7	2·6	2·9	2·5	1·7	1·6	1·2	0·9	.....	.....	1·2
3·3	5·8	8·6	11·2	13·4	14·0	13·1	11·3	10·3	8·8	6·9	.....	.....	7·6
0·82	1·45	2·15	2·80	3·35	3·50	3·28	2·82	2·58	2·20	1·72	.....	.....	1·90
0·50	1·13	1·83	2·48	3·03	3·18	2·96	2·50	2·26	1·88	1·40	.....	.....	1·58

at Singapore, Eastern Archipelago.

3·57	4·29	5·29	5·04	5·09	4·40	3·80	3·69	3·54	3·19	2·85	.....	.....	2·86
3·23	4·31	5·10	5·04	4·53	4·14	3·47	2·97	3·15	2·83	2·44	.....	.....	2·77
3·40	4·30	5·19	5·04	4·81	4·27	3·63	3·33	3·34	3·01	2·64	.....	.....	2·81
3·36	4·26	5·15	5·00	4·77	4·23	3·59	3·29	3·30	2·97	2·60	.....	.....	2·77

Borneo, Eastern Archipelago.—Declinometer No. II.

0·17	0·00	0·16	0·63	0·93	1·24	1·35	0·99	0·88	0·55	0·63	0·57	0·57	0·93
0·15	0·01	0·00	0·36	1·28	1·67	2·11	1·69	1·39	1·31	1·35	1·23	1·18	1·26
0·08	0·00	0·42	1·03	1·50	2·36	2·41	1·87	1·35	1·06	1·16	0·93	0·75	1·22
0·40	0·01	0·58	2·02	3·71	5·27	5·87	4·55	3·62	2·92	3·14	2·73	2·50	3·41
0·13	0·00	0·19	0·67	1·24	1·76	1·96	1·52	1·21	0·97	1·05	0·98	0·83	1·14
0·13	0·00	0·19	0·67	1·24	1·76	1·96	1·52	1·21	0·97	1·05	0·98	0·83	1·14

Eastern Archipelago.—Declinometer No. II.

0·98	2·59	3·80	4·16	3·80	3·12	2·53	2·43	2·20	1·61	1·23	.....	.....	1·78
2·45	3·69	4·40	4·61	4·39	4·04	3·51	3·14	2·98	2·56	2·27	.....	.....	2·42
3·01	4·53	5·41	5·71	6·10	5·76	5·08	4·07	3·88	3·56	3·21	.....	.....	3·29
2·28	3·78	4·69	5·14	5·29	4·96	4·12	3·63	3·87	3·16	2·77	.....	.....	2·77
8·72	14·59	18·30	19·62	19·58	17·88	15·24	13·27	12·93	10·89	9·48	.....	.....	10·26
2·18	3·65	4·58	4·91	4·89	4·47	3·81	3·32	3·24	2·72	2·37	.....	.....	2·56
2·09	3·56	4·49	4·82	4·80	4·38	3·72	3·23	3·15	2·63	2·28	.....	.....	2·47

Oscillation of the Declination at Singapore,

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	′	′	′	′	′	′	′	′	′	′	′
November .....1848...	.....	.....	.....	2·61	2·29	1·82	1·05	0·22	0·00	0·92	2·25
December	.....	.....	.....	2·72	2·50	2·25	1·29	0·00	0·04	1·28	2·50
Mean	.....	.....	.....	2·66	2·39	2·03	1·17	0·11	0·02	1·10	2·37
Oscillation	.....	.....	.....	2·64	2·37	2·01	1·15	0·09	0·00	1·08	2·35

Mean Hourly Oscillation of the Magnetic Declination at Singapore

December	2·34	2·34	2·27	2·16	2·08	1·72	0·88	0·00	0·01	0·64	1·49
January	2·43	2·35	2·24	2·10	1·88	1·53	0·91	0·03	0·00	0·62	1·15
February	2·88	2·82	2·80	2·82	2·67	2·47	1·93	0·78	0·04	0·00	0·52
Sums	7·65	7·51	7·31	7·08	6·63	5·72	3·72	0·81	0·05	1·26	3·16
Means	2·55	2·50	2·44	2·36	2·21	1·91	1·24	0·27	0·02	0·42	1·05
Oscillation	2·53	2·48	2·42	2·34	2·19	1·89	1·22	0·25	0·00	0·40	1·03

Mean Hourly Oscillation of the Magnetic Declina-

March	1·25	1·30	1·28	1·24	1·18	1·15	1·16	0·71	0·00	0·11	0·75
April	1·22	1·38	1·44	1·43	1·31	1·22	1·66	1·43	0·47	0·00	0·28
May	1·56	1·73	1·91	1·96	2·01	2·11	3·05	3·34	2·07	1·00	0·42
Sums	4·03	4·41	4·63	4·63	4·50	4·58	5·87	5·48	2·54	1·11	1·45
Means	1·34	1·47	1·54	1·54	1·50	1·53	1·96	1·83	0·85	0·37	0·48
Oscillation	0·97	1·10	1·17	1·17	1·13	1·16	1·59	1·46	0·48	0·00	0·11

Mean Hourly Oscillation of the Magnetic Declina-

June	0·55	0·78	0·86	1·00	1·03	1·21	1·96	2·32	1·23	0·62	0·00
July	0·77	1·01	1·20	1·13	1·15	1·65	2·44	2·87	1·89	0·78	0·15
August	1·81	2·01	2·09	2·18	2·24	2·52	3·66	4·05	2·59	1·13	0·23
Sums	3·13	3·80	4·15	4·31	4·42	5·38	8·06	9·24	5·71	2·53	0·38
Means	1·04	1·27	1·38	1·44	1·47	1·79	2·69	3·08	1·90	0·84	0·13
Oscillation	0·97	1·20	1·31	1·37	1·40	1·72	2·62	3·01	1·83	0·77	0·06

Mean Hourly Oscillation of the Magnetic Declina-

September	1·67	1·83	1·85	1·91	2·01	2·07	2·86	2·57	1·12	0·26	0·00
October	2·06	2·02	2·02	1·90	1·82	1·64	1·68	0·84	0·18	0·00	0·42
November	2·06	2·09	2·04	1·90	1·68	1·45	0·68	0·00	0·02	0·35	1·16
Sums	5·79	5·94	5·91	5·71	5·51	5·16	5·22	3·41	1·32	0·61	1·58
Means	1·93	1·98	1·97	1·90	1·84	1·72	1·74	1·14	0·44	0·20	0·53
Oscillation	1·73	1·78	1·77	1·70	1·64	1·52	1·54	0·94	0·24	0·00	0·33

Mean Hourly Oscillation of the Magnetic Decli-

Winter	2·53	2·48	2·42	2·34	2·19	1·89	1·22	0·25	0·00	0·40	1·03
Spring	0·97	1·10	1·17	1·17	1·13	1·16	1·59	1·46	0·48	0·00	0·11
Summer.....	0·97	1·20	1·31	1·37	1·40	1·72	2·62	3·01	1·83	0·77	0·06
Autumn.....	1·73	1·78	1·77	1·70	1·64	1·52	1·54	0·94	0·24	0·00	0·33
Sums	6·20	6·56	6·67	6·58	6·36	6·29	6·97	5·66	2·55	1·17	1·53
Means	1·55	1·64	1·67	1·64	1·59	1·57	1·74	1·41	0·64	0·29	0·38
Oscillation	1·26	1·35	1·38	1·35	1·30	1·28	1·45	1·12	0·35	0·00	0·09

Eastern Archipelago.—Declinometer No. II.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
3·64	4·52	5·68	5·40	5·50	4·80	4·19	4·15	3·94	3·68	3·32	.....	.....	3·16
3·55	4·53	5·42	5·50	4·90	4·51	3·86	3·31	3·38	3·18	2·85	.....	.....	3·03
3·60	4·52	5·55	5·45	5·20	4·65	4·02	3·73	3·66	3·43	3·08	.....	.....	3·09
3·58	4·50	5·53	5·43	5·18	4·63	4·00	3·71	3·64	3·41	3·06	.....	.....	3·07

in the Winter Months of 1843, 1844, 1845.—Scale Divisions.

2·60	3·70	4·40	4·43	4·35	4·20	3·60	3·19	3·01	2·86	2·65	2·49	2·41	2·49
1·80	2·97	3·74	4·09	4·00	3·70	3·29	3·14	3·17	2·97	2·85	2·66	2·46	2·34
2·12	3·36	4·32	4·63	4·49	4·08	3·72	3·43	3·39	3·21	3·02	2·84	2·81	2·70
6·52	10·03	12·46	13·15	12·84	11·98	10·61	9·76	9·57	9·04	8·52	7·99	7·68	7·53
2·17	3·34	4·15	4·38	4·28	3·99	3·54	3·25	3·19	3·01	2·84	2·66	2·56	2·51
2·15	3·32	4·13	4·36	4·26	3·97	3·52	3·23	3·17	2·99	2·82	2·64	2·54	2·49

tion in the Spring Months of 1843, 1844, 1845.

1·52	1·90	2·09	2·41	2·59	2·35	2·08	1·88	1·61	1·38	1·27	1·21	1·19	1·40
0·58	0·53	0·90	1·09	1·50	1·72	1·67	1·44	1·17	0·93	0·82	0·92	1·04	1·09
0·00	0·09	0·71	1·21	1·66	2·04	1·44	1·48	1·27	1·08	1·00	1·11	1·16	1·49
2·10	2·52	3·70	4·71	5·75	6·11	5·19	4·80	4·05	3·39	3·09	3·24	3·39	3·98
0·70	0·84	1·23	1·57	1·92	2·04	1·73	1·60	1·35	1·13	1·03	1·08	1·13	1·33
0·33	0·47	0·86	1·20	1·55	1·67	1·36	1·23	0·98	0·76	0·66	0·71	0·76	0·96

tion in the Summer Months of 1843, 1844, 1845.

0·22	0·29	0·62	0·79	0·89	0·77	0·54	0·15	0·04	0·03	0·04	0·08	0·25	0·58
0·00	0·07	0·55	0·89	1·26	1·49	1·31	0·74	0·48	0·35	0·31	0·39	0·52	0·99
0·00	0·32	0·95	1·46	2·25	2·39	2·66	2·14	1·91	1·63	1·52	1·51	1·66	1·89
0·22	0·68	2·12	3·14	4·40	4·65	4·51	3·03	2·43	2·01	1·87	1·98	2·43	3·46
0·07	0·23	0·71	1·05	1·47	1·55	1·50	1·01	0·81	0·67	0·62	0·66	0·81	1·15
0·00	0·16	0·64	0·98	1·40	1·48	1·43	0·94	0·74	0·60	0·57	0·59	0·74	1·08

tion in the Autumn Months of 1843, 1844, 1845.

0·26	0·71	1·34	1·97	2·43	2·37	2·26	2·15	1·91	1·68	1·60	1·53	1·55	1·97
1·50	2·77	3·38	3·42	3·20	2·86	2·61	2·59	2·40	2·18	2·03	1·92	1·88	1·97
2·37	3·61	4·25	4·41	4·17	3·61	3·05	2·88	2·72	2·46	2·27	2·01	2·03	2·22
4·13	7·09	8·97	9·80	9·80	8·84	7·92	7·62	7·03	6·32	5·90	5·46	5·46	6·16
1·38	2·36	2·99	3·27	3·27	2·95	2·64	2·54	2·34	2·11	1·97	1·82	1·82	2·05
1·18	2·16	2·79	3·07	3·07	2·75	2·44	2·34	2·14	1·91	1·77	1·62	1·62	1·85

nation in the four Seasons of 1843, 1844, 1845.

2·15	3·32	4·13	4·36	4·26	3·97	3·52	3·23	3·17	2·99	2·82	2·64	2·54	2·49
0·33	0·47	0·86	1·20	1·55	1·67	1·36	1·23	0·98	0·76	0·66	0·71	0·76	0·96
0·00	0·16	0·64	0·98	1·40	1·48	1·43	0·94	0·74	0·60	0·57	0·59	0·74	1·08
1·18	2·16	2·79	3·07	3·07	2·75	2·44	2·34	2·14	1·91	1·77	1·62	1·62	1·85
3·66	6·11	8·42	9·61	10·28	9·87	8·75	7·74	7·03	6·26	5·82	5·56	5·66	6·38
0·91	1·53	2·11	2·40	2·57	2·47	2·19	1·93	1·76	1·56	1·45	1·39	1·41	1·59
0·62	1·24	1·82	2·11	2·28	2·18	1·90	1·64	1·47	1·27	1·16	1·10	1·12	1·30

Mean Hourly Oscillation of the Magnetic Declina-

Singapore Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
December	2·34	2·34	2·27	2·16	2·08	1·72	0·88	0·00	0·01	0·64	1·49
January	2·43	2·35	2·24	2·10	1·88	1·53	0·91	0·03	0·00	0·62	1·15
February	2·88	2·82	2·80	2·82	2·67	2·47	1·93	0·78	0·04	0·00	0·52
March	1·25	1·30	1·28	1·24	1·18	1·15	1·16	0·71	0·00	0·11	0·75
April	1·22	1·38	1·44	1·43	1·31	1·22	1·66	1·43	0·47	0·00	0·28
May	1·56	1·73	1·91	1·96	2·01	2·11	3·05	3·34	2·07	1·00	0·42
June	0·55	0·78	0·86	1·00	1·03	1·21	1·96	2·32	1·23	0·62	0·00
July	0·77	1·01	1·20	1·13	1·15	1·65	2·44	2·87	1·89	0·78	0·15
August	1·81	2·01	2·09	2·18	2·24	2·52	3·66	4·05	2·59	1·13	0·23
September	1·67	1·83	1·85	1·91	2·01	2·07	2·86	2·57	1·12	0·26	0·00
October	2·06	2·02	2·02	1·90	1·82	1·64	1·68	0·84	0·18	0·00	0·42
November	2·06	2·09	2·04	1·90	1·68	1·45	0·68	0·00	0·02	0·35	1·16
Sums	20·60	21·66	22·00	21·73	21·06	20·74	22·87	18·94	9·62	5·51	6·57
Means	1·72	1·81	1·88	1·81	1·76	1·78	1·91	1·58	0·80	0·46	0·55
Oscillation	1·26	1·35	1·37	1·35	1·30	1·27	1·45	1·12	0·35	0·00	0·09

Mean Oscillation of the Magnetic Declination at Singapore

1843	1·31	1·37	1·41	1·32	1·30	1·20	1·36	1·02	0·37	0·00	0·10
1844	1·36	1·46	1·49	1·51	1·46	1·41	1·57	1·23	0·38	0·00	0·04
1845	1·13	1·21	1·24	1·24	1·21	1·20	1·41	1·13	0·37	0·00	0·14
Sums	3·80	4·04	4·14	4·07	3·97	3·81	4·34	3·38	1·12	0·00	0·28
Oscillation	1·27	1·35	1·38	1·36	1·32	1·27	1·45	1·13	0·37	0·00	0·09

tion for each Month of the Years 1843, 1844, 1845.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
2·60	3·70	4·40	4·43	4·35	4·20	3·60	3·19	3·01	2·86	2·65	2·49	2·41	2·49
1·80	2·97	3·74	4·09	4·00	3·70	3·29	3·14	3·17	2·97	2·85	2·66	2·46	2·34
2·12	3·36	4·32	4·63	4·49	4·08	3·72	3·43	3·39	3·21	3·02	2·84	2·81	2·70
1·52	1·90	2·09	2·41	2·59	2·35	2·08	1·88	1·61	1·38	1·27	1·21	1·19	1·40
0·58	0·53	0·90	1·09	1·50	1·72	1·67	1·44	1·17	0·93	0·82	0·92	1·04	1·09
0·00	0·09	0·71	1·21	1·66	2·04	1·44	1·48	1·27	1·08	1·00	1·11	1·16	1·49
0·22	0·29	0·62	0·79	0·89	0·77	0·54	0·15	0·04	0·03	0·04	0·08	0·25	0·58
0·00	0·07	0·55	0·89	1·26	1·49	1·31	0·74	0·48	0·35	0·31	0·39	0·52	0·99
0·00	0·32	0·95	1·46	2·25	2·39	2·66	2·14	1·91	1·63	1·52	1·51	1·66	1·89
0·26	0·71	1·34	1·97	2·43	2·37	2·26	2·15	1·91	1·68	1·60	1·53	1·55	1·97
1·50	2·77	3·38	3·42	3·20	2·86	2·61	2·59	2·40	2·18	2·03	1·92	1·88	1·97
2·37	3·61	4·25	4·41	4·17	3·61	3·05	2·88	2·72	2·46	2·27	2·01	2·03	2·22
12·97	20·32	27·25	30·80	32·79	31·58	28·23	25·21	23·08	20·76	19·38	18·67	18·96	21·13
1·08	1·69	2·27	2·57	2·73	2·63	2·35	2·10	1·92	1·73	1·61	1·55	1·58	1·76
0·61	1·22	1·80	2·10	2·27	2·17	1·90	1·64	1·46	1·27	1·15	1·09	1·12	1·30

during the three years of 1843, 1844, 1845, in Scale Divisions.

0·58	1·20	1·84	2·09	2·24	2·20	1·89	1·52	1·42	1·24	1·18	1·08	1·16	1·27
0·51	1·19	1·84	2·18	2·38	2·28	1·96	1·70	1·50	1·35	1·19	1·13	1·20	1·35
0·57	1·16	1·62	1·92	2·14	2·14	1·94	1·68	1·48	1·24	1·08	0·99	1·02	1·22
1·66	3·55	5·30	6·19	6·76	6·62	5·79	4·90	4·40	3·83	3·45	3·20	3·38	
0·56	1·19	1·78	2·07	2·25	2·20	1·92	1·63	1·47	1·28	1·15	1·06	1·12	1·28

TABLE A.

Observatory at Moulmein.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000343=1'{\cdot}000343$. Declinometer No. II.				
Sums	366·6	362·6	360·7	365·8	370·7	369·7	372·2	367·8	361·4	355·5
Means of 7 days	52·37	51·80	51·53	52·26	52·96	52·81	53·17	52·54	51·63	50·79
Diurnal changes	+0·2	−0·4	−0·7	+0·1	+0·8	+0·6	+1·0	+0·3	−0·6	−1·4
Diurnal oscillation	1·6	1·0	0·7	1·5	2·2	2·0	2·4	1·7	0·8	0·0
Diurnal declination	19′ 21″ +2°	18·45	18′ 27″	19′ 15″	19′ 57″	19′ 45″	20′ 09″	19′ 27″	18′ 33″	17′ 45″
						$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}004\times1{\cdot}0004=1'{\cdot}0044$. Declinometer No. III.				
Sums	593·3	590·1	588·9	592·2	596·4	597·9	597·9	594·9	588·9	582·9
Means of 5 days	118·66	118·02	117·78	118·44	119·28	119·58	119·58	118·98	117·78	116·58
Diurnal changes	+0′·4	−0′·3	−0′·5	+0′·1	+1′·0	+1·3	+1′·3	+0′·7	−0′·5	−1′·7
Diurnal oscillation	2·3	1′·6	1′·4	2′·0	2′·9	3·2	3′·2	2′·6	1′·4	0′·2
Diurnal declination	19′ 15″ +2°	18′ 33″	18′ 21″	18′ 57″	19′ 51″	20′ 09″	20′ 09″	19′ 33″	18′ 21″	17′ 09″

Observatory at Madras.—Hourly observations made during the Months of

						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}00047=1'{\cdot}00047$. Declinometer No. I.				
Sums	2713·0	2713·7	2715·9	2738·0	2777·3	2790·2	2755·7	2718·6	2678·6	2650·0
Means of 34 days	79·79	79·81	79·88	80·53	81·69	82·06	81·05	79·96	78·78	77·94
Diurnal changes	−0′·21	−0′·19	−0′·12	+0′·53	+1′·69	+2′·06	+1′·05	−0′·04	−1′·22	−2′·06
Diurnal oscillation	1′·85	1′·87	1′·94	2′·59	3′·75	4′·12	3′·11	2′·02	0′·84	0′·00
Diurnal declination	54′ 53″ 0°	54′ 55″	54′ 59″	55′ 38″	56′ 47″	57′ 10″	56′ 09″	55′ 04″	53′ 53″	53′ 02″
						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}00034=1'{\cdot}00034$. Declinometer No. II.				
Sums	1276·1	1276·0	1280·3	1308·7	1345·0	1358·2	1333·1	1303·6	1272·1	1249·4
Means of 33 days	38·67	38·67	38·80	39·66	40·76	41·15	40·40	39·50	38·55	37·86
Diurnal changes	−0′·53	−0′·53	−0′·40	+0′·46	+1′·56	+1′·95	+1′·20	+0′·30	−0′·65	−1′·34
Diurnal oscillation	0′·81	0′·81	0′·94	1′·80	2′·90	3′·29	2′·54	1′·64	0′·69	0′·00
Diurnal declination	54′ 25″ 0°	54′ 25″	54′ 33″	55′ 25″	56′ 31″	56′ 54″	56′ 09″	55′ 15″	54′ 18″	53′ 37″

TABLE A.

Month of April, 1849. Latitude 16° 29′ 46″ N. Longitude 97° 45′ 30″ E.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from 14th to 21st, 53·17. $\alpha = 2° 20′ 09″$ East.												
	355·6	358·1	363·0	368·8	371·7	371·4	368·6	365·5	364·9	6940·6	365·2	
	50·80	51·16	51·86	52·69	53·10	53·06	52·66	52·21	52·13	991·53	52·18	2° 19′ 09″
	−1′·4	−1′·0	−0′·3	+0′·5	+0′·9	+0′·9	+0′·5	0′·0	−0′·1			
	0·0	0·4	1·1	1·9	2·3	2·3	1·9	1·4	1·3			
	17′ 45″	18′ 09″	18′ 51″	19′ 39″	20′ 03″	20′ 03″	19′ 39″	19′ 09″	19′ 03″			
Zero from 16th to 21st, 119·58. $\alpha = 2° 20′ 19″$ East.												
	582·2	584·5	589·5	595·5	598·4	596·6	592·8	589·9	588·9	11241·7	591·7	
	116·44	116·90	117·90	119·10	119·68	119·32	118·56	117·98	117·78	2248·34	118·32	2° 18′ 51″
	−1′·9	−1′·4	−0′·4	+0′·8	+1′·4	+1′·0	+0′·3	−0′·3	−0′·5			
	0·0	0′·5	1′·5	2′·7	3·3	2′·9	2′·2	1′·6	1′·4			
	16′ 47″	17′ 27″	18′ 27″	19′ 39″	20′ 15″	19′ 51″	19′ 09″	18′ 33″	18′ 21″			

August and September, 1849. Latitude 13° 04′ 09″ N. Longitude 80° 16′ 00″ E.

Zero from August 22nd to September 29th, 81·05. $\alpha = 0° 56′ 09″$ East.												
	2653·4	2682·8	2712·9	2742·4	2745·1	2733·9	2725·2	2718·8	2716·6	51682·1	2719·9	
	78·04	78·91	79·79	80·66	80·74	80·41	80·15	79·86	79·90	1520·05	80·00	0° 55′ 96″
	−1′·96	−1′·09	−0′·21	+0′·16	+0′·74	+0′·41	+0′·15	−0′·04	−0′·10			
	0′·10	0′·97	1′·85	2′·72	2′·80	2′·47	2′·21	2′·02	1′·96			
	53′ 08″	53′ 07″	54′ 53″	55′ 46″	55′ 50″	55′ 31″	55′ 15″	55′ 04″	55′ 00″			
Zero from August 22nd to September 29th, 40·40. $\alpha = 0° 56′ 09″$ East.												
	1254·2	1278·7	1304·8	1319·8	1312·3	1293·6	1282·4	1271·4	1266·9	24586·6	1294·2	
	38·01	38·75	39·54	39·99	39·77	39·20	38·86	38·53	38·39	745·06	39·20	
	−1′·09	−0′·45	+0′·34	+0′·79	+0′·57	0′·00	−0′·34	−0′·67	−0′·81			
	0′·25	0′·89	1′·68	2′·13	1′·91	1′·34	1′·00	0′·67	0′·53			
	53′ 52″	54′ 30″	55′ 17″	55′ 44″	55′ 31″	54′ 57″	54′ 37″	54′ 17″	54′ 08″			

TABLE A.

Observatory at Madras.—Hourly observations made during the Months of August

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
					$a\left(1+\frac{H}{F}\right)=1'{\cdot}0047\times1{\cdot}0004=1'{\cdot}0051$. Declinometer No. III.					
Sums	351·8	355·0	356·5	384·0	431·8	437·3	400·0	354·9	314·1	285·5
Means of 33 days	10·66	10·76	10·80	11·64	13·08	13·25	12·12	10·75	9·52	8·65
Diurnal changes	−0′·01	+0′·09	+0′·13	+0′·97	+2′·41	+2′·58	+1′·45	+0′·08	−1′·15	−2′·02
Diurnal oscillation	2′·01	2′·11	2′·15	2′·99	4′·43	4′·60	3′·47	2′·10	0′·87	0′·00
Diurnal declination	54′ 41″ 0°	54′ 47″	54′ 50″	55′ 40″	55′ 11″	57′ 17″	56′ 09″	54′ 47″	53′ 38″	52′ 41″

Observatory at Car Nicobar.—Hourly observations made during the

					$a\left(1+\frac{H}{F}\right)=1'\times1{\cdot}00047=1'{\cdot}00047$. Declinometer No. I.					
Sums	426·7	425·5	422·9	419·2	418·3	420·4	428·4	435·2	438·9	439·6
Means of 5 days	85·34	85·10	84·58	83·84	83·66	84·08	85·68	87·04	87·78	87·92
Diurnal changes	−1′·00	−1′·24	−1′·76	−2′·50	−2′·68	−2′·26	−0′·66	+0′·70	+1′·44	+1′·58
Diurnal oscillation	1′·68	1′·44	0′·92	0′·18	0′·00	0′·42	2′·02	3′·38	4′·12	4′·26
Diurnal declination	51′ 39″ +1°	51′ 25″	50′ 53″	49′ 09″	49′ 58″	50′ 23″	51′ 59″	53′ 21″	54′ 07″	54′ 14″
					$a\left(1+\frac{H}{F}\right)=1'\times1{\cdot}00034=1'{\cdot}00034$. Declinometer No. II.					
Sums	250·0	249·0	247·2	243·2	242·8	244·7	203·0	257·6	261·4	261·7
Means of 5 days	50·00	49·80	49·44	48·64	48·56	48·94	50·75	51·52	52·28	52·34
Diurnal changes	−0′·83	−1′·03	−1′·39	−2′·19	−2′·27	−1′·89	−0′·08	+0′·69	+1′·45	+1′·51
Diurnal oscillation	1′·44	1′·24	0′·88	0′·08	0′·00	0′·38	2′·19	2′·96	3′·72	3′·78
Diurnal declination	51′ 50″ +1°	51′ 38″	51′ 16″	50′ 28″	50′ 23″	50′ 46″	52′ 35″	53 21″	54′ 07″	54′ 10″
					$a\left(1+\frac{H}{F}\right)=1'{\cdot}004\times1{\cdot}0004=1'{\cdot}004$. Declinometer No. III.					
Sums	505·6	504·9	502·8	499·3	499·4	503·3	510·2	517·0	519·3	519·8
Means of 5 days	101·12	100·98	100·56	99·86	99·88	100·66	102·04	103·40	103·86	103·96
Diurnal changes	−1′·20	−1′·34	−1′·76	−2′·46	−2′·44	−1′·66	−0′·28	+1′·08	+1′·54	+1′·64
Diurnal oscillation	1′·26	1′·12	0′·70	0′·00	0′·02	0′·80	2′·18	3′·54	4′·00	4′·10
Diurnal declination	51′ 04″ +1°	50′ 56″	50′ 31″	49′ 49″	49′ 50″	50′ 37″	51′ 59″	53′ 21″	53′ 47″	53′ 55″

Table A.

and September, 1849. Latitude 13° 04′ 09″ N. Longitude 80° 16′ 00″ E. (*Continued.*)

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from August 22nd to September 29th, 12·12. $\alpha = 0°56'09''$ East.											
287·2	308·4	341·0	364·3	365·5	346·8	338·8	333·2	332·7	6688·8	351·9	
8·70	9·35	10·33	11·04	11·08	10·51	10·27	10·10	10·08	202·69	10·67	
−1′·97	−1′·32	−0′·34	+0′·37	+0′·41	−0′·16	−0′·40	−0′·57	−0′·59			
0′·05	0′·70	1′·68	2′·39	2′·43	1′·86	1′·62	1′·45	1′·43			
52′ 44″	53′ 23″	54′ 22″	55′ 04″	55′ 07″	54′ 32″	54′ 18″	54′ 08″	54′ 07″			

Month of February 1849. Latitude 9° 10′ 12″ N. Longitude 92° 48′ 23″ N.

Zero from 6th to 10th of February, 87·04. $\alpha = 1°53'21''·2$ East.											
440·9	442·0	440·2	438·3	436·1	432·2	433·6	432·8	432·0	8203·2	431·7	
88·18	88·40	88·04	87·66	87·22	86·44	86·72	86·56	86·40	1640·64	86·34	1° 52′ 39″
+1′·84	+2′·06	+1′·70	+1′·32	+0′·88	+0′·10	+0′·38	+0′·22	+0′·06			
4′·52	4′·74	4′·38	4′·00	3′·56	2′·78	3′·06	2′·90	2′·74			
54′ 29″	54′ 43″	54′ 21″	53′ 58″	53′ 31″	52′ 45″	53′ 02″	52′ 52″	52′ 43″			
Zero from February 6th to 10th, 51·52. $\alpha = 1°53'21''$ East.											
262·7	263·3	261·3	259·0	256·8	252·4	254·3	254·0	253·4	4777·8	254·1	
52·54	52·66	52·26	51·80	51·36	50·48	50·86	50·80	50·68	965·71	50·83	1° 52′ 40″
+1′·71	+1′·83	+1′·43	+0′·97	+0′·53	−0′·35	+0′·03	−0′·03	−0′·15			
3′·98	4′·10	3′·70	3′·24	2′·80	1′·92	2′·30	2′·24	2′·12			
54′ 22″	54′ 29″	54′ 05″	53′ 38″	53′ 11″	51′ 19″	52′ 41″	52′ 38″	52′ 31″			
Zero from February 6th to 10th, 103·40. $\alpha = 1°53'21''$ East.											
520·4	520·4	519·1	516·8	514·6	408·9	410·1	409·8	409·4	9311·1	511·3	
104·08	104·08	103·82	103·36	102·92	102·23	102·53	102·45	102·35	1944·14	102·32	1° 52′ 16″
+1′·76	+1′·76	+1′·50	+1′·04	+0′·60	−0′·09	+0′·21	+0′·13	+0′·03			
4′·22	4′·22	3′·96	3′·50	3′·06	2′·37	2′·67	2′·59	2′·49			
54′ 03″	54′ 02″	53′ 46″	53′ 19″	52′ 52″	52′ 11″	52′ 29″	52′ 24″	52′ 18″			

TABLE A.

Observatory at Samboangan.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$\alpha\left(1+\frac{H}{F}\right)=1' \times 1{\cdot}000204+1'{\cdot}000204$. Declinometer No. I.				
Sums	527·0	527·3	527·5	530·4	532·4	528·6	521·0	514·0	512·8	508·9
Means of 6 days	87·83	87·88	87·92	88·40	88·73	88·10	86·83	85·67	85·47	84·82
Diurnal changes	+1′·15	+1′·20	+1′·24	+1′·72	+2′·05	+1′·42	+0′·15	−1′·01	−1′·21	−1′·86
Diurnal oscillation	3′·01	3′·06	3′·10	3′·58	3′·91	3′·28	2′·01	0′·85	0′·65	0′·00
Diurnal declination	17′ 34″ +1°	17′ 37″	17′ 39″	18′ 08″	18′ 28″	17′ 50″	16′ 34″	15′ 24″	15′ 12″	14′ 33″
						$\alpha\left(1+\frac{H}{F}\right)=1' \times 1{\cdot}000250=1'{\cdot}00025$. Declinometer No. II.				
Sums	316·3	316·6	316·4	319·5	318·4	259·2	256·4	303·4	303·5	297·0
Means of 6 days	52·72	52·77	52·73	53·25	53·07	51·84	51·28	50·57	50·58	49·50
Diurnal changes	+1′·28	+1′·33	+1′·29	+1′·81	+1′·63	+0′·40	−0′·16	−0′·87	−0′·86	−1′·94
Diurnal oscillation	3′·22	3′·27	3′·23	3′·75	3′·57	2′·34	1′·78	1′·07	1′·08	0′·00
Diurnal declination	17′ 33″ +1°	17′ 36″	17′ 34″	18′ 05″	17′ 54″	16′ 40″	16′ 07″	15′ 24″	15′ 25″	14′ 20″

Observatory at Penang.—Hourly observations made during the

						$\alpha\left(1+\frac{H}{F}\right)=1' \times 1{\cdot}00047=1'{\cdot}00047$. Declinometer No. I.				
Sums	434·1	434·0	432·2	427·3	424·0	427·5	435·7	444·0	443·9	448·5
Means of 5 days	86·82	86·80	86·44	85·46	84·80	85·50	87·14	88·80	88·78	89·70
Diurnal changes	−0′·76	−0′·78	−1′·14	−2′·12	−2′·78	−2′·08	−0′·44	+1′·22	+1′·20	+2′·12
Diurnal oscillation	2′·02	2′·00	1′·64	0′·66	0′·00	0′·70	2′·34	4′·00	3′·98	4′·90
Diurnal declination	47′ 47″ +1°	47′ 46″	47′ 24″	46′ 25″	45′ 46″	46′ 28″	48′ 06″	49′ 46″	49′ 44″	50′ 40″
						$\alpha\left(1+\frac{H}{F}\right)=1' \times 1{\cdot}00034=1'{\cdot}00034$. Declinometer No. II.				
Sums	258·6	258·7	256·7	251·7	247·3	250·7	258·9	264·0	262·8	268·5
Means of 5 days	51·72	51·74	51·34	50·34	49·46	50·14	51·78	52·80	52·56	53·70
Diurnal changes	−0′·16	−0′·14	−0′·54	−1′·54	−2′·42	−1′·74	−0′·10	+0′·92	+0′·68	+1′·82
Diurnal oscillation	2′·26	2′·28	1′·88	0′·88	0′·00	0′·68	2′·32	3′·34	3′·10	4′·24
Diurnal declination	48′ 02″ +1°	48′ 04″	47′ 40″	46′ 40″	45′ 47″	46′ 28″	48′ 06″	49′ 07″	48′ 53″	50′ 00″

TABLE A.

Month of May, 1848. Latitude 6° 54′ 20″ N. Longitude 122° 13′ 45″ E.

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from 25th to 31st, 85·67. $\alpha = 1° 15′ 24″$ East.											
509·9	511·2	512·3	516·3	520·3	520·9	521·4	520·1	519·5	9881·8	520·1	
84·98	85·20	85·38	86·05	86·72	86·82	86·90	86·68	86·58	1646·96	86·68	1° 16′ 25″
−1′·70	−1′·48	−1′·30	−0′·63	+0′·04	+0′·14	+0′·22	0′·00	−0′·10			
0′·16	0′·38	0′·56	1′·23	1′·90	2′·00	2′·08	1′·86	1′·76			
14′ 43″	14′ 56″	14′ 07″	15′ 47″	16′ 27″	16′ 33″	16′ 38″	16′ 25″	16′ 19″			
Zero from 25th to 31st, 50·57. $\alpha = 1° 15′ 24″$ East.											
297·9	300·9	301·6	306·6	310·0	310·0	309·9	308·7	308·9	5761·2	308·6	
49·65	50·15	50·27	51·10	51·67	51·67	51·65	51·45	51·48	977·40	51·44	1° 16′ 16″
−1′·79	−1′·29	−1′·17	−0′·34	+0′·23	+0′·23	+0′·21	+0′·01	+0′·04			
0′·15	0′·65	0′·77	1′·60	2′·17	2′·17	2′·15	1′·95	1′·98			
14′ 29″	14′ 59″	15′ 06″	15′ 56″	16′ 30″	16′ 30″	16′ 29″	16′ 17″	16′ 19″			

Month of January, 1849. Latitude 5° 25′ 36″ N. Longitude 100° 24′ 38″ E.

Zero from the 22nd to the 26th, 78·14. $\alpha = 1° 48′ 06″$.											
448·3	446·7	444·9	443·1	438·5	436·0	437·1	437·6	436·9	8320·3	437·8	
89·66	89·34	88·98	88·62	87·70	87·20	87·42	87·52	87·38	1664·06	87·58	1° 48′ 32″
+2′·08	+1′·76	+1′·40	+1′·04	+0′·12	−0′·38	−0′·16	−0′·06	−0′·20			
4′·86	4′·54	4′·18	3′·82	2′·90	2′·40	2′·62	2′·72	2′·58			
50′ 37″	50′ 18″	49′ 56″	49′ 35″	48′ 40″	48′ 10″	48′ 24″	48′ 29″	48′ 20″			
Zero from the 22nd to the 26th, 51·78. $\alpha = 1° 48′ 06″$.											
268·1	266·4	264·5	262·4	258·3	253·5	256·7	256·5	255·6	4919·9	259·0	
53·62	53·28	52·90	52·48	51·66	50·70	51·34	51·30	51·12	983·98	51·88	
+1′·74	+1′·40	+1′·02	+0′·60	−0′·22	−1′·18	−0′·54	−0′·58	−0′·76			
4′·16	3′·82	3′·44	3′·02	2′·20	1′·24	1′·88	1′·84	1′·66			
49′ 56″	49′ 36″	49′ 13″	48′ 48″	47′ 59″	47′ 01″	47′ 40″	47′ 37″	47′ 26″			

TABLE A.

Observatory at Penang.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}004\times1{\cdot}0004=1'{\cdot}004$. Declinometer No. III.										
Sums	516·2	517·3	514·5	508·7	506·5	509·2	518·8	524·6	527·3	532·9
Means of 5 days ...	103·24	103·46	102·90	101·74	101·30	101·84	103·76	104·92	105·46	106·58
Diurnal changes ...	−1′·23	−1′·01	−1′·57	−2′·73	−3′·17	−2′·63	−0′·71	+0′·45	+0′·99	+2′·11
Diurnal oscillation...	1′·94	2′·16	1′·60	0′·44	0′·00	0′·54	2′·46	3′·62	4′·16	5′·28
Diurnal declination .	47′ 35″ +1°	47′ 48″	47′ 14″	46′ 05″	45′ 38″	46′ 11″	48′ 06″	49′ 16″	49′ 48″	50′ 55″

Observatory at Pulo Dinding.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}0005=1'{\cdot}0005$. Declinometer No. I.										
Sums	266·7	265·7	264·8	262·8	257·6	255·6	260·2	268·2	272·6	276·1
Means of 3 days ...	88·90	88·57	88·27	87·60	85·87	85·20	86·73	89·40	90·87	92·03
Diurnal changes.....	−0′·82	−1′·15	−1′·45	−2′·12	−3′·85	−4′·52	−2′·99	−0′·32	+1′·15	+2′·31
Diurnal oscillation...	3′·70	3′·37	3′·07	2′·40	0′·67	0′·00	1′·53	4′·20	5′·67	6′·83
Diurnal declination .	48′ 04″ +1°	47′ 44″	47′ 26″	46′ 46″	45′ 02″	44′ 22″	45′ 54″	48′ 34″	50′ 02″	51′ 19″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000445=1'{\cdot}000445$. Declinometer No. II.										
Sums	140·4	139·0	138·2	135·8	130·6	128·2	133·3	141·6	145·7	147·5
Means of 3 days ...	46·80	46·33	46·07	45·27	43·53	42·73	44·43	47·20	48·57	49·17
Diurnal changes ...	−0·48	−0·95	−1′·21	−2′·01	−3′·75	−4′·55	−2′·85	−0′·08	+1′·29	+1′·89
Diurnal oscillation...	4′·07	3′·60	3′·34	2′·54	0′·80	0′·00	1′·70	4′·47	5′·84	6′·44
Diurnal declination .	48′ 10″ +1°	47′ 42″	47′ 26″	46′ 38″	44′ 54″	44′ 06″	45′ 48″	48′ 34″	49′ 56″	50′ 32″
$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}004\times1{\cdot}0006=1'{\cdot}0046$. Declinometer No. III.										
Sums	301·8	301·2	300·6	297·6	293·4	292·6	298·1	306·7	311·1	314·0
Means of 3 days ...	100·60	100·40	100·20	99·20	97·80	97·53	99·37	102·23	103·70	104·67
Diurnal changes ...	−1′·31	−1′·51	−1′·71	−2′·71	−4′·11	−4′·38	−2′·54	+0′·32	+1′·79	+2′·76
Diurnal oscillation...	3′·07	2′·87	2′·67	1′·67	0′·27	0′·00	1′·84	4′·70	6′·17	7′·14
Diurnal declination .	46′ 56″ +1°	46′ 44″	46′ 32″	45′ 32″	44′ 08″	43′ 52″	45′ 42″	48′ 34″	50′ 02″	51′ 00″

TABLE A.

Month of May, 1848. Latitude 6° 54′ 20″ N. Longitude 122° 13′ 45″ E.

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 22nd to the 26th, 103·76. $\alpha = 1° 48' 06''$.											
534·6	531·7	530·6	529·1	525·8	523·7	524·6	525·1	523·5	9924·7	522·3	
106·92	106·34	106·12	105·82	105·16	104·74	104·92	105·02	104·70	1984·94	104·47	
+2′·45	+1′·87	+1′·65	+1′·35	+0′·69	+0′·27	+0′·45	+0′·55	+0′·23			
5′·62	5′·04	4′·82	4′·52	3′·86	3′·44	3′·62	3′·72	3′·40			
51′ 16″	50′ 41″	50′ 28″	50′ 10″	49′ 30″	49′ 05″	49′ 16″	49′ 22″	49′ 02″			

Month of January, 1849. Latitude 4° 12′ 48″ N. Longitude 100° 32′ 52″ E.

Zero from the 11th to the 13th, 89·4. $\alpha = 1° 48' 34''$.											
277·3	278·0	277·8	275·5	273·0	271·0	271·5	270·4	269·4	5114·2	269·2	
92·43	92·67	92·60	91·83	91·00	90·33	90·50	90·13	89·80	1704·73	39·72	1° 48′ 53″
+2′·71	+2′·95	+2′·88	+2′·11	+1′·28	+0′·61	+0′·78	+0′·41	+0′·08			
7′·23	7′·47	7′·40	6′·63	5′·80	5′·13	5′·30	4′·93	4′·60			
51′ 36″	51′ 50″	51′ 46″	51′ 00″	50′ 10″	49′ 30″	49′ 40″	49′ 18″	48′ 58″			
Zero from the 11th to the 13th, 47·20. $\alpha = 1° 48' 34''$.											
148·7	150·4	150·5	148·6	146·0	143·4	143·8	142·1	141·3	2695·1	141·8	
49·57	50·13	50·17	49·53	48·67	48·70	47·93	47·37	47·10	898·37	47·28	
+2′·29	+2′·85	+2′·89	+2′·25	+1′·39	+0′·52	+0′·65	+0′·09	−0′·18			
6′·84	7′·40	7′·44	6′·80	5′·94	5′·07	5′·20	4′·64	4′·37			
50′ 56″	51′ 30″	51′ 32″	50′ 54″	50′ 02″	49′ 10″	49′ 18″	48′ 44″	48′ 28″			
Zero from the 11th to the 13th, 102·23. $\alpha = 1° 48' 34''$.											
315·8	316·5	315·8	312·7	309·4	306·2	306·3	305·0	304·0	5808·8	305·7	
105·27	105·50	105·27	104·23	103·13	102·07	102·10	101·67	101·33	1936·27	101·91	
+3′·36	+3′·59	+3′·36	+2′·32	+1′·22	+0′·16	+0′·19	−0′·24	−0′·58			
7′·74	7′·97	7′·74	6′·70	5′·60	4′·54	4′·57	4′·14	3′·80			
51′ 36″	52′ 02″	51′ 36″	50′ 34″	49′ 28″	48′ 24″	48′ 26″	48′ 00″	47′ 40″			

Table A.

Observatory at Sarawak.—Hourly observations made during the

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158.$ Declinometer No. I.													
Sums	2229·2	2234·8	2240·6	2245·4	2246·4	2251·4	2264·4	2283·1	2269·0	2243·8	2223·3	2209·7	2200·9
Means of 26 days	85·74	85·95	86·18	86·36	86·40	86·59	87·09	87·81	87·27	86·30	85·51	84·99	84·65
Diurnal changes	−0′·03	+0′·18	+0′·41	+0′·59	+0′·63	+0′·82	+1′·32	+2′·04	+1′·50	+0′·53	−0′·26	−0′·78	−1′·12
Diurnal oscillation	1′·17	1′·38	1′·61	1′·79	1′·83	2′·02	2′·52	3′·24	2′·70	1′·73	0′·96	0′·42	0′·08
Diurnal declination	09′ 06″ +1°	09′ 19″	09′ 33″	09′ 44″	09′ 46″	09′ 57″	10′ 27″	11′ 11″	10′ 38″	09′ 40″	08′ 53″	08′ 21″	08′ 01″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139.$ Declinometer No. II.													
Sums	1364·1	1369·1	1374·1	1377·0	1377·0	1380·7	1393·0	1411·1	1395·8	1373·4	1358·0	1351·8	1295·6
Means of 26 days	52·47	52·66	52·85	52·96	52·96	53·10	53·58	54·27	53·68	52·82	52·23	51·99	51·82
Diurnal changes	−0′·28	−0′·09	+0′·10	+0′·21	+0′·21	+0′·35	+0′·83	+1′·52	+0′·93	+0′·07	−0′·52	−0′·76	−0′·93
Diurnal oscillation	0′·65	0′·84	1′·03	1′·14	1′·14	1′·28	1′·76	2′·45	1′·86	1′·00	0′·41	0′·17	0′·00
Diurnal declination	09′ 19″ +1°	09′ 30″	09′ 42″	09′ 48″	09′ 48″	09′ 57″	10′ 26″	11′ 07″	10′ 32″	09′ 40″	09′ 05″	08′ 50″	08′ 40″

Hourly observations made during

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158.$ Declinometer No. I.													
Sums	2342·0	2345·6	2353·9	2358·7	2364·4	2368·3	2381·6	2399·3	2384·0	2358·9	2340·6	2328·1	2322·4
Means of 27 days	86·74	86·87	87·18	87·36	87·57	87·71	88·21	88·86	88·30	87·37	86·69	86·23	86·02
Diurnal changes	−0′·20	−0′·07	+0′·24	+0′·42	+0′·63	+0′·77	+1′·27	+1′·92	+1′·36	+0′·43	−0′·25	−0′·71	−0′·92
Diurnal oscillation	0′·80	0′·93	1′·24	1′·42	1′·63	1′·77	2′·27	2′·92	2′·36	1′·43	0′·75	0′·29	0′·08
Diurnal declination	09′ 02″ +1°	09′ 10″	09′ 29″	09′ 39″	09′ 52″	10′ 00″	10′ 30″	11′ 09″	10′ 36″	09′ 40″	09′ 59″	09′ 32″	08′ 19″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139.$ Declinometer No. II.													
Sums	1425·1	1426·0	1450·9	1434·7	1436·2	1435·6	1442·6	1455·7	1387·4	1416·8	1400·0	1399·1	1395·4
Means of 25 days	57·00	57·04	58·04	57·39	57·45	57·42	57·70	58·23	57·81	56·67	56·00	55·96	55·82
Diurnal changes	−0′·07	−0′·03	+0′·97	+0′·32	+0′·38	+0′·35	+0′·63	+1′·16	+0′·74	−0′·40	−1′·07	−1′·11	−1′·25
Diurnal oscillation	1′·19	1′·23	2′·23	1′·58	1′·64	1′·61	1′·89	2′·42	2′·00	0′·86	0′·19	0′·15	0′·01
Diurnal declination	9′ 00″ +1°	10′ 02″	11′ 02″	10′ 23″	10′ 27″	10′ 25″	10′ 42″	11′ 14″	10′ 48″	9′ 40″	9′ 00″	8′ 57″	8′ 49″

Table A.

Month of June, 1846. Latitude 1° 33′ 54″ N. Longitude 110° 29′ 00″ E.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Declin.
Zero from the 1st to the 30th, 86·30. α=1° 09′ 40″ East.														
	2198·7	2205·9	2212·7	2221·4	2222·4	2217·2	2220·8	2217·6	2219·8	2221·4	2222·8	53322·7	2230·0	
	84·57	84·84	85·10	85·44	85·48	85·28	85·42	85 29	85·38	85·44	85·49	2058·57	85·77	1° 09′ 08″
	−1′·20	−0′·93	−0′·67	−0′·33	−0′·29	−0′·49	−0′·35	−0′·48	−0′·39	−0′·33	−0′·28			
	0′·00	0′·27	0′·53	0′·87	0′·91	0′·71	0′·85	0′·72	0′·81	0′·87	0′·92			
	07′ 56″	09′ 12″	08′ 28″	08′ 48″	08′ 51″	08′ 39″	08′ 47″	08′ 39″	08′ 45″	08′ 48″	08′ 51″			
Zero from the 1st to the 30th, 52·82. α=1° 09′ 40″ East.														
	1299·4	1363·7	1371·6	1326·5	1382·3	1373·0	1370·2	1361·7	1363·6	1362·2	1362·1	32757·0	1371·7	
	51·98	52·45	52·75	53·06	53·17	52·81	52·70	52·37	52·45	52·39	52·39	1265·91	52·75	1° 09′ 40″
	−0′·77	−0′·30	0′·00	+0′·31	+0′·42	+0′·06	−0′·05	−0′·38	−0′·30	−0′·36	−0′·36			
	0′·16	0′·63	0′·93	1′·24	1′·35	0′·99	0′·88	0′·55	0′·63	0′·57	0′·57			
	08′ 47″	09′ 18″	08′ 36″	09′ 54″	10′ 01″	09′ 39″	09′ 33″	09′ 13″	09′ 18″	09′ 14″	09′ 14″			

the Month of July 1846.

Zero from the 1st to the 31st, 87·37. α=1° 09′ 40″ East.														
	2320·5	2323·4	2332·1	2341·7	2349·6	2341·5	2337·6	2334·9	2334·3	2335·3	2336·4	56335·1	2347·1	
	85·94	86·05	86·37	86·73	87·02	86·72	86·58	86·48	86·46	86·49	86·53	2086·48	86·94	1° 09′ 14″
	−1′·00	−0′·89	−0′·57	−0′·21	+0′·08	−0′·22	−0′·36	−0′·46	−0′·48	−0′·45	−0′·41			
	0′·00	0′·11	0′·43	0′·79	1′·08	0′·78	0′·64	0′·54	0′·52	0′·55	0′·59			
	08′ 14″	08′ 21″	08′ 40″	09′ 02″	09′ 19″	09′ 01″	08′ 53″	08′ 47″	08′ 45″	08′ 47″	08′ 50″			
Zero from the 1st to the 31st, 56·67. α=1° 09′ 40″ East.														
	1339·4	1404·3	1370·2	1437·0	1390·0	1437·6	1429·9	1428·0	1428·9	1425·9	1424·7	34011·4	1426·4	
	55·81	56·17	57·09	57·48	57·92	57·50	57·20	57·12	57·16	57·09	56·99	1369·61	57·07	1° 9′ 16″
	−1′·26	−0′·90	+0′·02	+0′·41	+0′·85	+0′·43	+0′·13	+0′·05	+0′·09	−0′·03	−0′·08			
	0′·00	0′·36	1′·28	1′·67	2′·11	1′·69	1′·39	1′·31	1′·35	1′·23	1′·18			
	8′ 48″	9′ 10″	10′ 05″	10′ 29″	10′ 55″	10′ 30″	10′ 12″	10′ 07″	10′ 09″	10′ 02″	9′ 59″			

TABLE A.

Observatory at Sarawak.—Hourly observations made during the

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.													
Sums	1652·4	1653·2	1655·2	1659·5	1662·3	1665·8	1679·1	1699·1	1688·8	1661·8	1645·1	1632·4	1630·0
Means of 19 days	86·97	87·01	87·12	87·34	87·49	87·67	88·37	89·43	88·88	87·46	86·58	85·92	85·79
Diurnal changes	−0′·24	−0′·20	−0′·09	+0′·13	+0′·28	+0′·46	+1′·16	+2′·22	+1′·67	+0′·25	−0′·23	−1′·29	−1′·42
Diurnal oscillation	1′·18	1′·22	1′·33	1′·55	1′·70	1′·88	2′·58	3′·64	3′·09	1′·67	1′·19	0′·13	0′·00
Diurnal declination	09′ 11″ +1°	09′ 13″	09′ 20″	09′ 33″	09′ 42″	09′ 52″	10′ 34″	11′ 38″	11′ 05″	09′ 40″	09′ 11″	08′ 08″	08′ 00″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.													
Sums	1146·5	1146·7	1149·7	1151·4	1152·8	1158·0	1171·1	1187·6	1179·2	1155·3	1143·3	1135·0	1133·5
Means of 19 days	60·34	60·35	60·51	60·60	60·67	60·95	61·64	62·51	62·06	60·81	60·17	59·74	59·66
Diurnal changes	−0′·54	−0′·53	−0′·37	−0′·28	−0′·21	+0′·07	+0′·76	+1′·63	+1′·18	−0′·07	−0′·71	−1′·14	−1′·22
Diurnal oscillation	0′·68	0′·69	0′·85	0′·94	1′·01	1′·29	1′·98	2′·85	2′·40	1′·15	0′·51	0′·08	0′·00
Diurnal declination	09′ 12″ +1°	09′ 12″	09′ 22″	09′ 27″	09′ 32″	09′ 48″	10′ 30″	11′ 22″	10′ 55″	09′ 40″	10′ 02″	08′ 36″	08′ 31″

Observatory at Keemah.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000278=1'{\cdot}000278$. Declinometer No. I.													
Sums	.....	.....	.....	839·6	838·1	840·1	840·3	852·6	761·2	831·6	820·3	730·1	645·6
Means of 10 days	.....	.....	.....	83·96	83·81	84·01	84·03	85·26	84·58	83·16	82·03	81·12	80·70
Diurnal changes	.....	.....	.....	+0′·98	+0′·83	+1′·03	+1′·05	+2′·28	+1′·60	+0′·18	−0′·95	−1′·86	−2′·28
Diurnal oscillation	.....	.....	.....	3′·26	3′·11	3′·31	3′·33	4′·56	3′·88	2′·46	1′·33	0′·42	0′·00
Diurnal declination	.....	.....	.....	40′ 35″ +1	40′ 26″	40′ 38″	40′ 39″	41′ 53″	41′ 12″	39′ 47″	38′ 39″	37′ 45″	37′ 19″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000222=1'{\cdot}000222$. Declinometer No. II.													
Sums	.....	.....	.....	520·3	518·0	520·4	522·4	528·2	471·7	512·2	504·5	451·2	450·2
Means of 10 days	.....	.....	.....	52·03	51·80	52·04	52·24	52·82	52·41	51·22	50·45	50·13	50·02
Diurnal changes	.....	.....	.....	+0′·56	+0′·33	+0′·57	+0′·77	+1′·35	+0′·94	−0′·25	−1′·02	−1′·34	−1′·45
Diurnal oscillation	.....	.....	.....	2′·01	1′·78	2′·02	2′·22	2′·80	2′·39	1′·20	0′·43	0′·11	0′·00
Diurnal declination	.....	.....	.....	40′ 36″ +1°	40′ 22″	40′ 36″	40′ 48″	41′ 23″	40′ 58″	39′ 47″	39′ 01″	38′ 42″	38′ 35″

TABLE A.

Month of August, 1846. Latitude 1° 33′ 54″ N. Longitude 110° 29′ 00″ E.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Declin.
Zero from the 1st to the 22nd, 87·46. $\alpha = 1° 09′ 40″$ East.														
	1634·3	1642·4	1649·4	1661·7	1665·3	1657·7	1569·7	1567·0	1569·7	1567·2	1564·8	39333·9	1657·0	
	86·02	86·44	86·81	87·46	87·65	87·25	87·21	87·06	87·21	87·07	86·93	2087·87	87·21	1° 09′ 25″
	−1′·19	−0′·77	−0′·40	+0′·25	+0′·44	+0′·04	0′·00	−0′·15	0′·00	−0′·14	0′·28			
	0′·23	0′·65	1′·02	1′·67	1′·86	1′·46	1′·42	1′·27	1′·42	1′·28	1′·14			
	08′ 14″	08′ 39″	09′ 01″	09′ 40″	09′ 51″	09′ 27″	09′ 25″	09′ 16″	09′ 25″	09′ 17″	09′ 08″			
Zero from the 1st to the 22nd, 60·81. $\alpha = 1° 09′ 40″$ East.														
	1141·5	1153·1	1162·1	1176·5	1179·3	1169·0	1098·2	1092·9	1094·7	1090·6	1087·3	27455·3	1157·0	
	60·08	60·69	61·16	61·92	62·07	61·53	61·01	60·72	60·82	60·59	60·41	1462·59	60·88	1° 09′ 44″
	−0′·80	−0′·19	+0′·28	+1′·14	+1′·19	+0′·65	+0′·13	−0′·16	−0′·06	−0′·29	−0′·47			
	0′·42	1′·03	1′·50	2′·36	2′·41	1′·87	1′·35	1′·06	1′·16	0′·93	0′·75			
	08′ 56″	09′ 33″	10′ 01″	10′ 53″	10′ 56″	10′ 23″	09′ 52″	09′ 35″	09′ 41″	09′ 27″	09′ 16″			

Month of June, 1848. Latitude 1° 21′ 55″ N. Longitude 125° 07′ 59″ E.

Zero from the 21st of June to July 1st, 83·16. $\alpha = 1° 39′ 47″$ East.														
	731·1	738·1	824·4	828·2	829·3	829·2	830·6	829·4	828·6	.....	.....	15268·4	830·0	
	81·23	82·01	82·44	82·82	82·93	82·92	83·06	82·94	82·86	.....	.....	1575·87	82·98	1° 39′ 36″
	−1′·75	−0′·97	−0′·54	−0′·16	−0′·05	−0′·06	+0′·08	−0′·04	−0′·12	.....	.....			
	0′·53	1′·31	1′·74	2′·12	2′·23	2′·22	2′·36	2′·24	2′·16	.....	.....			
	37′ 51″	38′ 38″	39′ 04″	39′ 27″	39′ 33″	39′ 33″	39′ 41″	39′ 34″	39′ 29″	.....	.....			
Zero from the 21st of June to July 1st, 51·22. $\alpha = 1° 39′ 47″$ East.														
	507·2	512·1	514·8	517·1	517·7	516·1	515·6	514·6	511·5	.....	.....	9625·8	514·6	
	50·72	51·21	51·48	51·71	51·77	51·61	51·56	51·46	51·15	.....	.....	977·83	51·47	1° 40′ 02″
	−0′·75	−0′·26	+0′·01	+0′·24	+0′·30	+0′·14	+0′·09	−0′·01	−0′·32	.....	.....			
	0′·70	1′·19	1′·46	1′·69	1′·75	1′·59	1′·54	1′·44	1′·13	.....	.....			
	38′ 17″	39′ 46″	40′ 03″	40′ 16″	40′ 20″	40′ 10″	40′ 07″	40′ 01″	39′ 43″	.....	.....			

TABLE A.

Observatory at Keemah.—Hourly observations made during the Month of

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$\alpha\left(1+\right)=1'{\cdot}004\times1{\cdot}000306=1'{\cdot}0043$. Declinometer No. III.				
Sums	1028·1	1026·4	1028·0	1028·6	1037·0	927·0	1020·0	1013·1	910·2	910·7
Means of 10 days	102·81	102·64	102·80	102·86	103·70	103·00	102·00	101·31	101·13	101·19
Diurnal changes	+0′·16	−0′·01	+0′·15	+0′·21	+1′·05	+0′·35	−0′·65	−1′·34	−1′·52	−1′·46
Diurnal oscillation	1′·68	1′·51	1′·67	1′·73	2′·57	1′·87	0′·87	0′·18	0′·00	0′·06
Diurnal declination	40′ 36″ +1°	40′ 25″	40′ 35″	40′ 39″	41′ 29″	40′ 47″	39′ 47″	39′ 06″	38′ 55″	38′ 58″

Observatory at Pulo Peesang.—Hourly observations made during the

						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.				
Sums	.....	78·9	151·9	185·8	179·8	180·8	185·4	187·4	193·6	200·4
Means of 5 days	.....	39·45	37·47	37·16	35·96	36·16	37·08	37·48	38·72	40·08
Diurnal changes	.....	+0′·85	−1′·13	−1′·44	−2′·64	−2′·44	−1′·52	−1′·12	+0′·12	+1′·48
Diurnal oscillation	.....	3′·29	1′·51	1′·00	0′·20	0′·00	0′·92	1′·32	2′·56	3′·92
Diurnal declination	.....	33′ 29″ +1°	31′ 46″	31′ 12″	30′ 24″	30′ 12″	31′ 07″	31′ 31″	32′ 45″	34′ 07″
						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.				
Sums	.....	87·0	177·0	217·8	212·5	213·4	217·6	218·8	221·3	224·7
Means of 5 days	.....	43·50	44·25	43·56	42·50	42·68	43·52	43·76	44·26	44·94
Diurnal changes	.....	−0′·72	+0′·03	−0′·66	−1′·72	−1′·54	−0′·70	−0′·46	+0′·04	+0′·74
Diurnal oscillation	.....	1′·00	1′·75	1′·06	0′·00	0′·18	1′·02	1′·26	1′·76	2′·46
Diurnal declination	.....	31′ 08″ +1°	31′ 51″	31′ 09″	30′ 06″	30′ 17″	31′ 07″	31′ 21″	31′ 51″	32′ 33″

Observatory at Singapore.—Hourly observations made during the

						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000315=1'{\cdot}000305$. Declinometer No. I.				
Sums	223·1	216·8	210·2	197·0	185·8	187·3	200·6	220·3	241·2	253·6
Means of 16 days	13·94	13·55	13·14	12·31	11·61	11·71	12·54	13·77	15·08	15·85
Diurnal changes	−0′·57	−0′·92	−1′·33	−2′·16	−2′·86	−2′·76	−1′·93	−0′·70	+0′·61	+1′·38
Diurnal oscillation	2′·33	1′·94	1′·53	0′·70	0′·00	0′·10	0′·93	2′·16	3′·47	4′·24
Diurnal declination	36′ 53″ +1°	36′ 30″	36′ 05″	35′ 15″	34′ 33″	34′ 39″	35′ 29″	36′ 43″	38′ 01″	38′ 48″

Table A.

June and July, 1848. Latitude 1° 21′ 55″. Longitude 125° 07′ 59″ E.

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 21st of June to July 1st, 102·00. α=1° 89′ 47″ East.											
1019·5	1027·1	1031·4	1034·3	1034·4	1033·0	1031·7	1028·9	1025·8	19195·2	1026·4	
101·95	102·71	103·14	103·43	103·44	103·30	103·17	102·89	102·58	1950·05	102·65	1° 40′ 26″
−0′·70	+0′·06	+0′·49	+0′·78	+0′·79	+0′·65	+0′·52	+0′·24	−0′·07			
0′·82	1′·58	2′·01	2′·30	2′·31	2′·17	2′·04	1′·76	1′·45			
39′ 44″	40′ 30″	40′ 55″	41′ 13″	41′ 13″	41′ 05″	40′ 57″	40′ 40″	40′ 22″			

Month of January, 1846. Latitude 1° 27′ 53″ N. Longitude 103° 19′ 15″ E.

Zero from the 18th to the 22nd, 37·08. α=1° 31′ 07″ East.											
203·5	202·8	199·2	197·9	157·6	197·6	196·8	155·7	114·9	3165·0	193·1	
40·70	40·56	39·84	39·58	39·40	39·52	39·36	38·93	38·30	695·01	38·60	1° 32′ 30″
+2′·10	+1′·96	+1′·24	+0′·98	+0′·80	+0′·92	+0′·76	+0′·33	−0′·30			
4′·54	4′·40	3′·68	3′·42	3′·24	3′·36	3′·20	2′·77	2′·14			
34′ 44″	34′ 36″	33′ 53″	33′ 37″	33′ 26″	33′ 33″	33′ 24″	32′ 58″	32′ 20″			
Zero from the 18th to the 22nd. α=1° 31′ 07″ East.											
228·8	182·3	224·4	223·6	178·6	222·3	222·3	177·1	132·7	3582·2	221·0	
45·76	45·58	44·88	44·72	44·65	44·46	44·46	44·28	44·23	795·99	44·22	
+1′·54	+1′·36	+0′·66	+0′·50	+0′·43	+0′·24	+0′·24	+0′·06	+0′·01			
3′·26	3′·08	2′·38	2′·22	2′·15	1′·96	1′·96	1′·78	1′·73			
33′ 21″	33′ 11″	32′ 29″	32′ 19″	32′ 15″	32′ 03″	32′ 03″	31′ 53″	31′ 50″			

Month of November, 1848. Latitude 1° 18′ 32″ N. Longitude 103° 56′ 30″ E.

Zero from the 13th to the 30th, 12·54. α=1° 35′ 29″ East.											
269·3	266·0	266·8	255·4	245·9	245·6	243·4	239·0	232·8	4400·1	231·7	
16·83	16·63	16·68	15·96	15·37	15·35	15·21	14·94	14·55	275·02	14·47	1° 37′ 25″
+2′·36	+2′·16	+2′·21	+1′·49	+0′·90	+0′·88	+0′·74	+0′·47	+0′·08			
5′·22	5′·02	5′·07	4′·35	3′·76	3′·74	3′·60	3′·33	2′·94			
39′ 46″	39′ 34″	39′ 37″	38′ 54″	38′ 19″	38′ 18″	38′ 09″	37′ 53″	37′ 30″			

TABLE A.

Observatory at Singapore.—Hourly observations made during the Month

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
					$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000371=1'{\cdot}000371$. Declinometer No. II.					
Sums	796·8	791·7	784·1	771·9	758·6	755·0	769·8	791·1	813·2	827·3
Means of 16 days	49·80	49·48	49·01	48·24	47·41	47·19	48·11	49·44	50·83	51·71
Diurnal changes	−0'·55	−0'·87	−1'·34	−2'·11	−2'·94	−3'·16	−2'·24	−0'·91	+0'·48	+1'·36
Diurnal oscillation	2'·61	2'·29	1'·82	1'·05	0'·22	0'·00	0'·92	2'·25	3'·64	4'·52
Diurnal declination	37′ 10″ +1°	36′ 51″	36′ 23″	35′ 37″	34′ 49″	34′ 34″	35′ 29″	36′ 49″	38′ 12″	39′ 05″
					$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}0047\times1{\cdot}00037=1'{\cdot}004$. Declinometer No. III.					
Sums	1563·3	1557·0	1549·9	1536·4	1527·6	1526·2	1541·3	1560·8	1583·3	1594·8
Means of 16 days	97·71	97·31	96·87	96·03	95·48	95·39	96·33	97·55	98·96	99·68
Diurnal changes	−0'·54	−0'·94	−1'·38	−2'·22	−2'·77	−2'·86	−1'·92	−0'·70	+0'·71	+1'·43
Diurnal oscillation	2'·32	1'·92	1'·48	0'·64	0'·09	0'·00	0'·94	2'·16	3'·57	4'·29
Diurnal declination	36′ 52″ +1°	36′ 28″	36′ 01″	35′ 11″	34′ 38″	34′ 33′	35′ 29″	36′ 39′	38′ 07″	38′ 50″
					$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}0005\times1{\cdot}0003=1'{\cdot}0008$. Declinometer No IV.					
Sums	1558·4	1472·3	1463·0	1449·7	1429·3	1427·0	1439·7	1456·4	1473·8	1486·2
Means of 16 days	97·40	98·15	97·53	96·65	95·29	95·13	95·98	97·09	98·25	99·08
Diurnal changes	−0'·71	+0'·04	−0'·58	−1'·46	−2'·82	−2'·98	−2'·13	−1'·02	+0'·14	+0'·97
Diurnal oscillation	2'·27	3'·02	2'·40	1'·52	0'·16	0'·00	0'·85	1'·96	3'·12	3'·95
Diurnal declination	36′ 54″ +1°	37′ 39″	37′ 02″	36′ 09″	34′ 48″	34′ 38″	35′ 29″	36′ 36″	37′ 45″	38′ 33″
					$\alpha\left(1+\frac{H}{F}\right)=40''{\cdot}7\times1{\cdot}000451$. Declinometer No. V.					
Sums	660·0	655·0	647·4	626·0	617·2	608·3	635·2	661·1	685·8	708·8
Means of 16 days	41·25	40·94	40·46	39·13	38·58	38·02	39·70	41·32	42·86	44·30
Diurnal changes	−0'·74	−0'·95	−1'·28	−2'·18	−2'·56	−2'·94	−1'·80	−0'·70	+0'·35	+1'·33
Diurnal oscillation	2'·20	1'·99	1'·66	0'·76	0'·38	0'·00	1'·14	2'·24	3'·29	4'·27
Diurnal declination	36′ 33″ +1°	36′ 20″	36′ 00″	35′ 06″	34′ 43″	34′ 21″	35′ 29″	36′ 35″	37′ 38″	38′ 37″

TABLE A

of November, 1848. Latitude 1° 18′ 32″ N. Longitude 103° 56′ 30″ E. (*Continued.*)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 13th to the 30th, 48·11. α=1° 35′ 29″ East.												
	845·9	841·4	843·1	831·9	822·0	821·4	818·1	813·9	808·2	15305·4	805·7	
	52·87	52·59	52·69	51·99	51·38	51·34	51·13	50·87	50·51	956·59	50·35	1° 37′ 43″
	+2′·52	+2′·24	+2′·34	+1′·64	+1′·03	+0′·99	+0′·78	+0′·52	+0′·16			
	5′·68	5′·40	5′·50	4′·80	4′·19	4′·15	3′·94	3′·68	3′·32			
	40′ 15″	39′ 58″	40′ 04″	39′ 22″	38′ 45″	38′ 43″	38′ 30″	38′ 15″	37′ 53″			
Zero from the 13th to the 30th, 96·33. α=1° 35′ 29″ East.												
	1610·8	1606·9	1607·6	1596·7	1587·1	1585·2	1582·9	1577·2	1571·9	29866·9	1572·0	
	100·68	100·43	100·48	99·79	99·19	99·08	98·93	98·58	98·24	1866·71	98·25	1° 37′ 23″
	+2′·43	+2′·18	+2′·23	+1′·54	+0′·94	+0′·83	+0′·68	+0′·33	−0′·01			
	5′·29	5′·04	5′·09	4′·40	3′·80	3′·69	3′·54	3′·19	2′·85			
	39′ 50″	39′ 35″	39′ 38″	38′ 57″	38′ 21″	38′ 14″	38′ 05″	37′ 44″	37′ 24″			
Zero from the 13th to the 30th, 95·98. α=1° 35′ 29″ East.												
	1502·6	1600·0	1603·2	1592·6	1585·4	1585·4	1576·4	1570·6	1563·3	28844·3	1569·7	
	100·17	100·00	100·20	99·54	99·09	99·09	98·53	98·21	97·71	1863·61	98·11	1° 37′ 37″
	+2′·06	+1′·89	+2′·09	+1′·43	+0′·98	+0′·98	+0′·42	+0′·10	−0′·40			
	5′·04	4′·87	5′·07	4′·41	3′·96	3′·96	3′·40	3′·00	2′·58			
	39′ 40″	39′ 30″	39′ 42″	39′ 03″	38′ 36″	38′ 36″	38′ 02″	37′ 38″	37′ 13″			
Zero from the 13th to the 30th, 39·70. α=1° 35′ 29″ East.												
	733·3	725·6	724·9	716·2	699·6	699·7	695·8	688·5	682·2	12870·6	677·3	
	45·83	45·35	45·31	44·76	43·73	43·73	43·49	43·03	42·64	804·43	42·34	1° 37′ 17″
	+2′·37	+2′·05	+2′·02	+1′·65	+0′·94	+0′·95	+0′·78	+0′·47	+0′·20			
	5′·31	4′·99	4′·96	4′·59	3′·88	3′·89	3′·72	3′·41	3′·14			
	39′ 39″	39′ 20″	39′ 18″	38′ 56″	38′ 13″	38′ 14″	38′ 04″	37′ 45″	37′ 29″			

TABLE A.

Observatory at Singapore.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000305=1'{\cdot}000305$. Declinometer No. I.										
Sums	203·3	199·5	195·0	181·9	170·0	172·9	187·9	201·7	213·6	228·6
Means of 14 days ...	14·52	14·25	13·93	12·99	12·14	12·35	13·42	14·41	15·26	16·33
Diurnal changes ...	−0′·30	−0′·57	−0′·89	−1′·83	−2′·68	−2′·47	−1′·40	−0′·41	+0′·44	+1′·51
Diurnal oscillation...	2·38	2′·11	1′·79	0′·85	0′·00	0′·21	1′·28	2′·27	3′·12	4′·19
Diurnal declination .	36′ 35″ +1°	36′ 20″	36′ 00″	35′ 03″	34′ 12″	34′ 25″	35′ 29″	36′ 28″	37′ 19″	38′ 24″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000371=1'{\cdot}000371$. Declinometer No. II.										
Sums	706·0	703·0	699·4	686·0	667·9	668·5	685·9	702·9	717·7	731·3
Means of 14 days ...	50·43	50·21	49·96	49·00	47·71	47·75	48·99	50·21	51·26	52·24
Diurnal changes ...	−0′·31	−0′·53	−0′·78	−1′·74	−3′·03	−2′·99	−1′·75	−0′·53	+0′·52	+1′·50
Diurnal oscillation...	2′·72	2′·50	2′·25	1′·29	0′·00	0′·04	1′·28	2′·50	3′·55	4′·53
Diurnal declination .	36′ 55″ +1°	36′ 42″	36′ 27″	35′ 30″	34′ 12″	34′ 15″	35′ 29″	36′ 42″	37′ 45″	38′ 44″
$\alpha\left(1+\frac{H}{F}\right)=1'{\cdot}0047\times1{\cdot}00037=1'{\cdot}004$. Declinometer No. III.										
Sums	1375·0	1371·5	1366·4	1353·7	1340·6	1344·2	1358·9	1373·7	1385·9	1401·0
Means of 14 days ...	98·21	97·96	97·60	96·69	95·76	96·01	97·06	98·12	98·99	100·07
Diurnal changes.....	−0′·32	−0′·57	−0′·93	−1′·84	−2′·77	−2′·52	−1′·47	−0′·41	+0′·46	+1′·54
Diurnal oscillation...	2′·45	2′·20	1′·84	0′·93	0′·00	0′·25	1′·30	2′·36	3′·23	4′·31
Diurnal declination .	36′ 38″ +1°	36′ 23″	36′ 01″	35′ 09″	34′ 11″	34′ 26″	35′ 29″	36′ 33″	37′ 25″	38′ 30″
$\alpha\left(1+\frac{H}{F}\right)=1'\,0005\times1{\cdot}0003=1'{\cdot}0008$. Declinometer No. IV.										
Sums	1345·2	1341·9	1337·5	1325·9	1308·3	1306·9	1320·3	1335·2	1347·9	1363·4
Means of 14 days ...	96·09	95 85	95·54	94·71	93·45	93·35	94·31	95·37	96·28	97·39
Diurnal changes ...	−0′·06	−0′·30	−0′·61	−1′·44	−2′·70	−2′·80	−1′·84	−0′·78	+0′·13	+1′·24
Diurnal oscillation...	2′·74	2′·50	2′·19	1′·36	0′·10	0′·00	0′·96	2′·02	2′·93	4′·04
Diurnal declination .	37′ 16″ +1°	37′ 01″	36′ 43″	35′ 53″	34′ 37″	34′ 31″	35′ 29″	36′ 33″	37′ 27″	38′ 34″

TABLE A.

Month of December, 1848. Latitude 1° 18′ 32″ N. Longitude 103° 56′ 30″ E.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 1st to the 16th, 13·42. α=1° 35′ 29″ East.												
	240·1	238·6	231·8	226·3	216·6	209·8	212·4	208·4	202·9	3941·3	207·6	
	17·15	17·04	16·56	16·16	15·47	14·99	15·17	14·89	14·49	281·52	14·82	1° 36′ 53″
	+2′·33	+2′·22	+1′·74	+1′·34	+0′·65	+0′·17	+0′·35	+0′·07	−0′·33			
	5′·01	4′·90	4′·42	4′·02	3′·33	2′·85	3′·03	2′·75	3′·01			
	39′ 13″	39′ 06″	38′ 37″	38′ 13″	37′ 32″	37′ 03″	37′ 14″	36′ 57″	37′ 13″			
Zero from the 1st to the 16th, 48·99. α=1° 35′ 29″ East.												
	743·8	744·9	736·5	731·1	722·0	714·3	715·3	712·5	707·8	13496·8	710·3	
	53·13	53·21	52·61	52·22	51·57	51·02	51·09	50·89	50·56	964·06	50·74	1° 37′ 14″
	+2′·39	+2′·47	+1′·87	+1′·48	+0′·83	+0′·28	+0′·35	+0′·15	−0′·18			
	5′·42	5′·50	4′·90	4′·51	3′·86	3′·31	3′·38	3′·18	2′·85			
	39′ 37″	39′ 42″	39′ 06″	38′ 43″	38′ 04″	37′ 31″	37′ 35″	37′ 23″	37′ 03″			
Zero from the 1st to the 16th, 97·06. α=1° 35′ 29″ East.												
	1412·1	1411·2	1404·1	1398·6	1389·2	1382·2	1384·8	1380·3	1374·8	26208·2	1379·2	
	100·86	100·80	100·29	99·90	99·23	98·73	98·91	98·59	98·20	1871·98	98·53	1° 36′ 57″
	+2′·33	+2′·27	+1′·76	+1′·37	+0′·70	+0′·20	+0′·38	+0′·06	−0′·33			
	5′·10	5′·04	4′·53	4′·14	3′·47	2′·97	3′·15	2′·83	2′·44			
	39′ 17″	39′ 13″	38′ 43″	38′ 19″	37′ 39″	37′ 09″	37′ 20″	37′ 01″	36′ 37″			
Zero from the 1st to the 16th, 94·31. α=1° 35′ 29″ East.												
	1375·6	1375·8	1368·1	1364·1	1357·2	1351·6	1353·9	1351·6	1345·2	25575·6	1345·9	
	98·26	98·27	97·72	97·44	96·94	96·54	96·71	96·54	96·09	1826·85	96·15	1° 37′ 19″
	+2′·11	+2′·12	+1′·57	+1′·29	+0′·79	+0′·39	+0′·56	+0′·39	−0′·06			
	4′·90	4′·92	4′·37	4′·09	3′·59	3′·19	3′·36	3′·19	3′·74			
	39′ 25″	39′ 27″	38′ 54″	38′ 37″	38′ 07″	37′ 43″	37′ 53″	37′ 43″	37′ 16″			

Table A.

Observatory at Singapore.—Hourly observations made during the Month

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=40''{\cdot}7\times1{\cdot}000451$. Declinometer No. V.										
Sums	592·5	588·0	583·0	562·4	546·0	554·7	570·8	589·5	607·0	626·7
Means of 14 days	42·32	42·00	41·64	40·17	39·00	39·62	40·77	42·11	43·36	44·76
Diurnal changes	−0′·37	−0′·58	−0′·83	−1′·83	−2′·63	−2′·20	−1′·42	−0′·51	+0′·34	+1′·29
Diurnal oscillation	2′·26	2′·05	1′·80	0′·80	0′·00	0′·43	1′·21	2′·12	2′·97	3′·92
Diurnal declination	36′ 32″ +1°	36′ 19″	36′ 04″	35′ 04″	34′ 16″	34′ 42″	35′ 29″	36′ 24″	37′ 15″	38′ 12″

Observatory at Pulo Booaya.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.										
Sums	.....	.....	126·1	161·9	160·9	162·8	165·6	169·5	173·6	175·8
Means of 4 days	.....	.....	42·03	40·48	40·23	40·70	41·40	42·38	43·40	43·95
Diurnal changes	.....	.....	−0′·29	−1′·84	−2′·09	−1′·62	−0′·92	+0′·06	+1′·08	+1′·63
Diurnal oscillation	.....	.....	1′·80	0′·25	0′·00	0′·47	1′·17	2′·15	3′·17	3′·72
Diurnal declination	.....	.....	29′ 27″ +1°	27′ 54″	27′ 39″	28′ 07″	28′ 49″	29′ 48″	30′ 49″	31′ 22″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.										
Sums	.....	.....	151·7	195·8	194·0	194·6	198·8	203·6	207·4	209·1
Means of 4 days	.....	.....	50·57	48·95	48·50	48·65	49·70	50·90	51·85	52·28
Diurnal changes	.....	.....	−0′·22	−1′·84	−2′·29	−2′·14	−1′·09	+0′·11	+1′·06	+1′·49
Diurnal oscillation	.....	.....	2′·07	0′·45	0′·00	0′·15	1′·20	2′·40	3′·35	3′·78
Diurnal declination	.....	.....	29′ 41″ +1°	28′ 04″	27′ 37″	27′ 46″	28′ 49″	30′ 01″	30′ 58″	31′ 24″

Observatory at Carimon Island.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.										
Sums	.....	.....	199·1	233·4	229·3	232·0	238·7	244·9	248·2	249·4
Means of 6 days	.....	.....	39·82	38·90	38·22	38·67	39·78	40·82	41·37	41·57
Diurnal changes	.....	.....	−0′·18	−1′·10	−1′·78	−1′·33	−0′·22	+0′·82	+1′·37	+1′·57
Diurnal oscillation	.....	.....	1′·60	0′·68	0′·00	0′·45	1′·56	2′·60	3′·15	3′·35
Diurnal declination	.....	.....	23′ 07″ +1°	22′ 12″	21′ 31″	21′ 58″	23′ 05″	24′ 07″	24′ 40″	24′ 52″

TABLE A.

of December, 1848. Latitude 1° 18′ 32″ N. Longitude 103° 56′ 30″ E. (*Continued.*)

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 1st to the 16th, 40·77. α=1° 35′ 29″ East.											
645·2	646·5	636·3	628·8	614·0	604·3	605·6	602·6	597·1	11401·0	600·1	
46·09	46·18	45·45	44·91	43·86	43·16	43·26	43·04	42·65	814·35	42·86	1° 37′ 34″
+2′·20	+2′·26	+1′·76	+1′·32	+0′·68	+0′·20	+0′·27	+0′·12	−0′·14			
4′·83	4′·89	4′·39	3′·95	3′·31	2′·83	2′·90	2′·75	2′·49			
39′ 02″	39′ 10″	38′ 40″	38′ 13″	37′ 35″	37′ 06″	37′ 10″	37′ 01″	36′ 46″			

Month of February, 1846. Latitude 0° 09′ 09″ N. Longitude 104° 21′ 00″ E.

Zero from the 6th to the 9th, 41·40. α=1° 28′ 49″ East.											
175·0	172·8	170·7	170·5	170·2	170·8	170·2	127·3	.....	2623·7	169·3	
43·75	43·20	42·68	42·63	42·55	42·70	42·55	42·43	.....	677·06	42·32	29′ 43″
+1′·43	+0′·88	+0′·36	+0′·31	+0′·23	+0′·38	+0′·23	+0′·11	.....			
3′·52	2′·97	2′·45	2′·40	2′·32	2′·47	2′·32	2′·20	.....			
31′ 10″	30′ 37″	30′ 06″	30′ 03″	29′ 58″	30′ 07″	29′ 58″	29′ 51″	.....			
Zero from the 6th to the 9th, 49·70. α=1° 28′ 49″ East.											
208·5	207·3	205·4	205·3	205·1	205·2	205·0	152·2	.....	3149·0	203·2	
52·13	51·83	51·35	51·33	51·28	51·30	51·25	50·73	.....	812·60	50·79	29′ 55″
+1′·34	+1′·04	+0′·56	+0′·54	+0′·49	+0′·51	+0′·46	−0′·06	.....			
3′·63	3′·33	2′·85	2′·83	2′·78	2′·80	2′·75	2′·23	.....			
31′ 15″	30′ 57″	30′ 28″	30′ 27″	30′ 24″	30′ 25″	30′ 22″	29′ 51″	.....			

Month of January, 1846. Latitude 0° 59′ 22″ N. Longitude 103° 27′ 00″ E.

Zero from the 26th to the 31st of January, 39·78. α=1° 23′ 05″ East.											
248·6	246·1	241·0	237·5	235·9	237·3	238·8	240·1	.....	3800·3	240·0	
41·43	41·02	40·17	39·58	39·32	39·55	39·80	40·02	.....	640·04	40·00	1° 23′ 17″
+1′·43	+1′·02	+0′·17	−0′·42	−0′·68	−0′·45	−0′·20	+0′·02	.....			
3′·21	2′·80	1′·95	1′·36	1′·10	1′·33	1′·58	1′·80	.....			
24′ 44″	24′ 19″	23′ 28″	22′ 53″	22′ 37″	22′ 51″	23 ′06″	23′ 19″	.....			

TABLE A.

Observatory at Carimon Island.—Hourly observations made during the Month of

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.										
Sums	.....	.....	233·1	271·5	268·2	273·7	281·3	289·0	293·6	296·2
Means of 6 days	.....	.....	46·62	45·25	44·70	45·62	46·88	48·17	48·93	49·37
Diurnal changes	.....	.....	−0′·91	−2′·28	−2′·83	−1′·91	−0′·65	+0′·64	+1′·40	+1′·84
Diurnal oscillation	.....	.....	1′·92	0′·55	0′·00	0′·92	2′·18	3′·47	4′·23	4′·67
Diurnal declination	.....	.....	22′ 49″ +1°	21′ 27″	20′ 54″	21′ 49″	23′ 05″	24′ 22″	25′ 08″	25′ 34″

Observatory at Padang.—Hourly observations made during the Month of

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000207=1'{\cdot}0002$. Declinometer No. I.										
Sums	953·6	952·6	952·8	872·1	947·6	942·3	940·0	934·2	943·6	959·7
Means of 12 days	79·46	79·38	79·40	79·28	78·97	78·53	78·33	77·85	78·63	79·97
Diurnal changes	−0′·12	−0′·20	−0′·18	−0′·30	−0′·61	−1′·05	−1′·25	−1′·73	−0′·95	−0′·39
Diurnal oscillation	1′·61	1′·53	1′·55	1′·43	1′·12	0′·68	0′·48	0′·00	0′·78	2′·12
Diurnal declination	26′ 03″ +1°	25′ 58″	25′ 59″	25′ 52″	25′ 33″	25′ 07″	24′ 55″	24′ 26″	25′ 13″	26′ 33″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. II.										
Sums	585·1	584·3	583·9	537·4	577·3	572·3	569·8	569·5	581·4	603·0
Means of 13 days	45·01	44·95	44·92	44·78	44·41	44·02	43·83	43·80	44·78	46·39
Diurnal changes	−0′·57	−0′·63	−0′·66	−0′·80	−0′·17	−1′·56	−1′·75	−1′·78	−0′·80	+0′·81
Diurnal oscillation	1′·21	1′·15	1′·12	0′·98	0′·61	0′·22	0′·03	0′·00	0′·98	2′·59
Diurnal declination	25′ 38″ +1°	25′ 32″	25′ 32″	25′ 26″	25′ 02″	24′ 38″	24′ 26″	24′ 26″	25′ 26″	27′ 02″

Observatory at Padang.—Hourly observations made during the Month

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000207=1'{\cdot}0002$. Declinometer No. I.										
Sums	2059·9	2060·6	2052·8	2034·2	2012·6	2016·1	2017·3	2030·6	2060·3	2085·3
Means of 26 days	79·23	79·25	78·95	78·24	77·41	77·54	77·59	78·10	79·24	80·20
Diurnal changes	−0′·06	−0′·04	−0′·34	−1′·05	−1′·88	−1′·75	−1′·70	−1′·19	−0′·05	+0′·91
Diurnal oscillation	1′·82	1′·84	1′·54	0′·83	0′·00	0′·13	0′·18	0′·69	1′·83	2′·79
Diurnal declination	25′ 32″ +1°	25′ 32″	25′ 14″	24′ 32″	23′ 44″	23′ 50″	23′ 56″	24′ 26″	25′ 32″	26′ 32″

TABLE A.

January, 1846. Latitude 0° 59′ 22″ N. Longitude 103° 27′ 00″ E. (*Continued.*)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 26th to the 31st, 46·88. α=1° 23′ 05″ East.												
	295·8	294·4	290·3	287·7	285·2	285·9	285·5	283·8	.....	4515·2	285·1	
	49·30	49·07	48·38	47·95	47·53	47·65	47·58	47·30	.....	760·30	47·53	1° 23′ 41″
	+1′·77	+1′·54	+0′·85	+0′·42	0′·00	+0′·12	+0′·05	−0′·23	.....			
	4′·60	4′·37	3′·68	3′·25	2′·83	2′·95	2′·88	2′·60	.....			
	25′ 30″	25′ 16″	24′ 35″	24′ 09″	23′ 44″	23′ 51″	23′ 47″	23′ 30″	.....			

October, 1847. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E.

Zero from the 17th to the 31st, 77·85. α=1° 24′ 26″ East.												
	969·1	971·7	969·0	968·1	963·4	961·6	958·5	955·5	950·1	18065·5	955·1	
	80·76	80·98	80·75	80·68	80·28	80·13	79·88	79·63	79·18	1512·07	79·58	1° 26′ 10″
	+1′·18	+1′·40	+1′·17	+1′·10	+0′·70	+0′·55	+0′·30	+0′·05	−0′·40			
	2′·91	3′·13	2′·90	2′·83	2′·43	2′·28	2′·03	1′·78	1′·33			
	27′ 21″	27′ 34″	27′ 20″	27′ 16″	26′ 52″	26′ 43″	26′ 28″	26′ 14″	25′ 40″			
Zero from the 16th to the 30th, 43·83. α=1° 24′ 26″ East.												
	618·8	623·5	618·9	563·0	556·0	601·0	598·0	592·1	585·4	11120·7	592·8	
	47·60	47·96	47·60	46·92	46·33	46·23	46·00	45·41	45·03	865·97	45·58	1° 26′ 14″
	+2′·02	+2′·38	+2′·02	+1′·34	+0′·75	+0′·65	+0′·42	−0′·17	−0′·55			
	3′·80	4′·16	3′·80	3′·12	2′·53	2′·43	2′·20	1′·61	1′·23			
	27′ 44″	28′ 38″	28′ 14″	27′ 32″	26′ 56″	26′ 50″	26′ 38″	26′ 02″	25′ 38″			

of November, 1847. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E.

Zero from the 1st to the 31st, 78·10. α=1° 24′ 26″ East.												
	2099·6	2102·3	2095·4	2088·9	2079·0	2073·9	2074·1	2066·8	2059·8	39169·5	2061·55	
	80·75	80·86	80·59	80·34	79·96	79·77	79·77	79·49	79·22	1506·50	79·29	1° 25′ 38″
	+1′·46	+1′·57	+1′·30	+1′·05	+0′·67	+0′·48	+0′·48	0′·20	−0′·07			
	3′·34	3′·45	3′·18	2′·93	2′·55	2′·36	2′·36	2′·08	1′·81			
	27′ 02″	27′ 14″	26′ 56″	26′ 38″	26′ 14″	26′ 08″	26′ 08″	25′ 50″	25′ 32″			

Table A.

Observatory at Padang.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
					$\alpha\left(1+\frac{H}{F}\right)=1' \times .000158=1'.000158$. Declinometer No. II.					
Sums	1154·7	1153·5	1145·9	1127·6	1103·2	1107·3	1110·6	1130·8	1166·8	1199·2
Means of 26 days	44·41	44·37	44·07	43·37	42·43	42·59	42·72	43·49	44·88	46·12
Diurnal changes	−0′·44	−0′·48	−0′·78	−1′·48	−2′·42	−2′·26	−2′·13	−1′·36	+0′·03	+1′·27
Diurnal oscillation	1′·98	1′·94	1′·64	0′·94	0′·00	0′·16	0′·29	1′·06	2′·45	3′·69
Diurnal declination	25′ 20″ +1°	25′ 20″	25′ 02″	24′ 20″	23′ 20″	23′ 32″	23′ 38″	24′ 26″	25′ 50″	27′ 02″

Observatory at Padang.—Hourly observations made during the

					$\alpha\left(1+\frac{H}{F}\right)=1' \times .000207=1'.002$. Declinometer No. I.					
Sums	2042·3	2039·9	2031·4	2013·5	1986·0	1970·1	1982·1	2000·1	2021·3	2052·6
Means of 26 days	78·55	78·46	78·13	77·44	76·38	75·77	76·23	76·93	77·74	78·95
Diurnal changes	+0′·21	+0′·12	−0′·21	−0′·90	−1′·96	−2′·57	−2′·11	−1′·41	−0′·60	+0′·61
Diurnal oscillation	2′·78	2′·69	2′·36	1′·67	0′·61	0′·00	0′·46	1′·16	1′·97	3′·18
Diurnal declination	26′ 02″ +1°	25′ 56″	25′ 38″	24′ 56″	23′ 56″	23′ 20″	24′ 38″	24′ 26″	25′ 14″	26′ 26″
					$\alpha\left(1+\frac{H}{F}\right)=1' \times .000158=1'.000158$. Declinometer No. II.					
Sums	1165·7	1163·8	1155·2	1139·2	1107·6	1096·5	1115·0	1143·5	1174·7	1214·2
Means of 26 days	44·83	44·76	44·43	43·82	42·60	42·17	42·88	43·98	45·18	46·70
Diurnal changes	−0′·63	−0′·70	−1′·03	−1′·64	−2′·86	−3′·29	−2′·58	−1′·48	−0′·28	+1′·24
Diurnal oscillation	2′·66	2′·59	2′·26	1′·65	0′·43	0′·00	0′·71	1′·81	3′·01	4′·53
Diurnal declination	25′ 14″ +1°	25′ 14″	24′ 50″	24′ 14″	23′ 02″	22′ 38″	23′ 20″	24′ 26″	25′ 38″	27′ 08″

Observatory at Padang.—Hourly observations made during the

					$\alpha\left(1+\frac{H}{F}\right)=1' \times .000207=1'.002$. Declinometer No. I.					
Sums	1003·5	1001·5	998·7	988·6	976·8	974·6	979·4	984·5	990·9	1006·1
Means of 13 days	77·19	77·04	76·82	76·05	75·14	74·97	75·34	75·73	76·22	77·39
Diurnal changes	+0′·20	+0′·05	−0′·17	−0′·94	−1′·85	−2′·02	−1′·65	−1′·26	−0′·77	+0′·40
Diurnal oscillation	2′·22	2′·07	1′·85	1′·08	0′·17	0′·00	0′·37	0′·76	1′·25	2′·42
Diurnal declination	25′ 56″ +1°	25′ 44″	25′ 32″	24′ 44″	25′ 02″	25′ 08″	24′ 50″	24′ 26″	24′ 56″	26′ 08″

Table A.

Month of November, 1847. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E. (*Continued.*)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 1st to the 30th, 43·49. $\alpha = 1° 24' 26''$ East.												
	1217·7	1223·0	1217·3	1208·1	1194·5	1184·7	1180·6	1169·9	1162·2	22157·6	1166·20	
	46·83	47·04	46·82	46·47	45·94	45·57	45·41	44·99	44·70	852·22	44·85	1° 25′ 44″
	+1′·98	+2′·19	+1′·97	+1′·62	+1′·09	+0′·72	+0′·56	+0′·14	−0′·15			
	4′·40	4′·61	4′·39	4′·04	3′·51	3′·14	2′·98	2′·56	2′·27			
	27′ 44″	27′ 56″	27′ 44″	27′ 26″	26′ 50″	26′ 32″	26′ 20″	25′ 56″	25′ 38″			

Month of December, 1847. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E.

Zero from the 1st to the 31st, 76·93. $\alpha = 1° 24' 26''$ East.												
	2067·6	2072·7	2080·5	2078·2	2066·0	2049·1	2051·9	2050·6	2044·2	38700·1	2036·6	
	79·52	79·72	80·02	79·93	79·46	78·81	78·92	78·87	78·62	1488·45	78·34	1° 25′ 50″
	+1′·18	+1′·38	+1′·68	+1′·59	+1′·12	+0′·47	+0′·58	+0′·53	+0′·28			
	3′·75	3′·95	4′·25	4′·16	3′·69	3′·04	3′·15	3′·10	2′·85			
	27′ 02″	27′ 14″	27′ 32″	27′ 26″	27′ 02″	26′ 20″	26′ 26″	26′ 26″	26′ 08″			
Zero from the 1st to the 31st, 43·98. $\alpha = 1° 24' 26''$ East.												
	1237·2	1244·9	1255·0	1246·3	1228·4	1202·3	1197·4	1189·0	1179·8	22455·7	1181·7	
	47·58	47·88	48·27	47·93	47·25	46·24	46·05	45·73	45·38	863·66	45·46	1° 25′ 56″
	+2′·12	+2′·42	+2′·81	+2′·47	+1′·79	+0′·78	+0′·59	+0′·27	−0′·08			
	5′·41	5′·71	6′·10	5′·76	5′·08	4′·07	3′·88	3′·56	3′·21			
	27′ 44″	28′ 10″	28′ 44″	28′ 20″	27′ 38″	26′ 38″	26′ 26″	26′ 08″	25′ 50″			

Month of January, 1848. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E.

Zero from the 1st to the 15th, 75·73. $\alpha = 1° 24' 26''$ East.												
	1013·6	1016·7	1019·4	1018·7	1010·9	1007·4	1015·2	1007·7	1003·5	19017·7	1001·0	
	77·97	78·21	78·42	78·36	77·76	77·49	78·09	77·52	77·19	1462·90	76·99	1° 25′ 44″
	+0′·98	+1′·22	+1′·43	+1′·37	+0′·77	+0′·50	+1′·10	+0′·53	+0′·20			
	3′·00	3′·24	3′·45	3′·39	2′·79	2′·54	3′·12	2′·55	2′·22			
	26′ 44″	26′ 56″	27′ 08″	27′ 08″	26′ 32″	26′ 14″	26′ 50″	26′ 14″	25′ 56″			

Table A.

Observatory at Padang.—Hourly observations made during the Month of

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. II.													
Sums	.....	.....	.....	585·7	583·3	579·4	569·7	558·4	557·7	567·4	576·4	587·3	606·9
Means of 13 days	.....	.....	.....	45·05	44·87	44·57	43·82	42·95	42·90	43·65	44·34	45·18	46·68
Diurnal changes	.....	.....	.....	−0′·62	−0′·80	−1′·10	−1′·85	−2′·72	−2′·77	−2′·02	−1′·33	−0′·49	+1′·01
Diurnal oscillation	.....	.....	.....	2′·15	1′·97	1′·67	0′·92	0′·05	0′·00	0′·75	1′·41	2′·28	3′·78
Diurnal declination	.....	.....	.....	25′ 08″ +1°	25′ 02″	24′ 44″	23′ 56″	23′ 02″	23′ 02″	23′ 44″	24′ 26″	25′ 20″	26′ 50″

Observatory at Poolo Bay.—Hourly observations made during the Months of

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000207=1'{\cdot}000207$. Declinometer No. I.													
Sums	.....	.....	.....	458·0	458·5	459·4	462·4	278·4	456·2	449·9	448·0	447·3	449·2
Means of 5 days	.....	.....	.....	91·60	91·70	91·88	92·48	92·80	91·24	89·98	89·60	89·46	89·84
Diurnal changes	.....	.....	.....	+0′·39	+0′·49	+0′·67	+1′·27	+1′·59	+0′·03	−1′·23	−1′·61	−1′·75	−1′·37
Diurnal oscillation	.....	.....	.....	2′·14	2′·24	2′·42	3′·02	3′·34	1′·78	0′·52	0′·14	0′·00	0′·38
Diurnal declination	.....	.....	.....	06′ 46″ +1°	06′ 52″	07′ 03″	07′ 39″	07′ 58″	06′ 25″	05′ 09″	05′ 32″	05′ 38″	05′ 01″
$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. II.													
Sums	.....	.....	.....	98·2	98·9	100·1	102·1	100·7	98·6	96·0	94·5	93·9	94·6
Means of 2 days	.....	.....	.....	49·10	49·45	50·05	51·05	50·35	49·30	48·00	47·25	46·95	47·30
Diurnal changes	.....	.....	.....	−0′·55	−0′·20	+0′·40	+1′·40	+0′·70	−0′·35	−1′·65	−2′·40	−2′·70	−2′·35
Diurnal oscillation	.....	.....	.....	2′·15	2′·50	3′·10	4′·10	3′·40	2′·35	1′·05	0′·30	0′·00	0′·35
Diurnal declination	.....	.....	.....	06′ 15″ +1°	06′ 36″	07′ 12″	08′ 12″	07′ 30″	06′ 27″	05′ 09″	04′ 24″	04′ 06″	04′ 27″

Observatory at Batavia.—Hourly observations made during the Month of

$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000207=1'{\cdot}000207$. Declinometer No. I.													
Sums	1514·8	1592·5	1593·3	1589·8	1589·0	1587·7	1570·5	1559·3	1556·0	1563·8	1576·9	1598·1	1623·6
Means of 19 days	84·16	83·82	83·86	83·67	83·63	83·56	82·66	82·07	81·89	82·30	82·99	84·11	85·45
Diurnal changes	0′·0	−0′·4	−0′·3	−0′·5	−0′·6	−0′·6	−1′·5	−2′·1	−2′·3	−1′·9	−1′·2	−0′·1	+1′·2
Diurnal oscillation	2′·3	1′·9	2′·0	1′·8	1′·7	1′·7	0′·8	0′·2	0′·0	0′·4	1′·1	2′·2	3′·3
Diurnal declination	49′ 01″ +0°	48′ 37″	48′ 43″	48′ 31″	48′ 25″	48′ 25″	47′ 31″	46′ 55″	46′ 43″	47′ 07″	47′ 49″	48′ 55″	50′ 13″

TABLE A.

January, 1848. Latitude 0° 58′ 58″ S. Longitude 100° 31′ 15″ E. (*Continued.*)

1	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Declin.
Zero from the 1st to the 15th, 44·34 α=1° 24′ 26″ East.													
618·7	624·5	626·5	622·2	611·2	604·9	608·0	598·8	593·7	.....	.....	11280·7	593·7	
47·59	48·04	48·19	47·86	47·02	46·53	46·77	46·06	45·67	.....	.....	867·74	45·67	1° 25′ 50″
+1′·92	+2′·37	+2′·52	+2′·19	+1′·35	+0′·86	+1′·10	+0′·39	0′·00	.....	.....			
4′·69	5′·14	5′·29	4′·96	4′·12	3′·63	3′·87	3′·16	2′·77	.....	.....			
27′ 44″	28′ 08″	28′ 20″	28′ 02″	27′ 08″	26′ 38″	26′ 56″	36′ 14″	25′ 50″	.....	.....			

August and September, 1847. Latitude 3° 53′ 54″ S. Longitude 102° 28′ 45″ E.

Zero from the 31st of August to September the 4th inclusive, 89·98. α=1° 05′ 09″ East.													
453·2	457·6	463·3	464·7	459·3	456·3	455·0	453·9	452·2	.....	.....	8482·8	456·1	
90·64	91·52	92·66	92·94	91·86	91·26	91·00	90·78	90·44	.....	.....	1733·68	91·21	1° 06′ 23″
−0′·57	+0′·31	+1′·45	+1′·73	+0′·65	+0′·05	−0′·21	−0′·43	−0′·77	.....	.....			
1′·18	2′·06	3′·20	3′·48	2′·40	1′·80	1′·54	1′·32	0′·98	.....	.....			
05′ 35″	06′ 41″	08′ 01″	08′ 07″	07′ 02″	06′ 26″	06′ 10″	05′ 57″	05′ 37″	.....	.....			
Zero from the 31st of August to September the 4th inclusive, 50·86. α=1° 05′ 09″ East.													
96·8	100·1	102·5	102·4	101·9	102·2	101·8	101·3	100·0	.....	.....	1886·6	99·3	
48·40	50·05	51·25	51·20	50·95	51·10	50·90	50·65	50·00	.....	.....	943·3	49·65	1° 06′ 48″
−1′·25	+0′·40	+1′·60	+1′·55	+1′·30	+1′·45	+1′·25	+1′·00	+0′·35	.....	.....			
1′·45	3′·10	4′·30	4′·25	4′·00	4′·15	3′·95	3′·70	3′·05	.....	.....			
05′ 33″	07′ 12″	08′ 24″	08′ 21″	08′ 06″	08′ 15″	08′ 03″	07′ 48″	07′ 09″	.....	.....			

November, 1846. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 9th to the 30th, 82·30. α=0° 47′ 07″ East.													
1643·3	1644·2	1638·5	1630·4	1623·9	1612·7	1610·5	1605·5	1603·1	1597·1	1597·3	38321·8	1600·2	
86·49	86·54	86·24	85·81	85·47	84·88	84·76	84·50	84·37	84·06	84·07	2021·36	84·22	0° 49′ 01″
+2′·3	+2′·3	+2′·0	+1′·6	+1′·3	+0′·7	+0′·6	+0′·3	+0′·2	−0′·1	−0′·1			
4′·6	4′·6	4′·3	3′·9	3′·6	3′·0	2′·9	2′·6	2′·5	2′·2	2′·2			
51′ 19″	51′ 19″	51′ 01″	50′ 37″	50′ 19″	49′ 43″	49′ 37″	49′ 19″	49′ 19″	48′ 55″	48′ 55″			

TABLE A.

Observatory at Batavia.—Hourly observations made during the

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.													
Sums	939·1	988·0	986·8	982·2	980·4	977·8	963·4	948·2	946·0	953·3	969·7	991·2	967·2
Means of 19 days ...	52·17	52·00	51·94	51·69	51·60	51·46	50·70	49·90	49·79	50·17	51·04	52·17	53·73
Diurnal changes ...	−0′·1	−0′·3	−0′·4	−0′·6	−0′·7	−0′·8	−1′·6	−2′·4	−2′·5	−2′·1	−1′·3	−0′·1	+1′·4
Diurnal oscillation...	2′·4	2′·2	2′·1	1′·9	1′·8	1′·7	0′·9	0′·1	0′·0	0′·4	1′·2	2′·4	3′·9
Diurnal declination .	49′ 07″ +0°	48′ 55″	48′ 49″	48′ 37″	48′ 31″	48′ 25″	47′ 57″	46′ 49″	46′ 43″	47′ 07″	47′ 55″	49′ 07″	50′ 37″

Observatory at Batavia.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000207=1'{\cdot}000207$. Declinometer No. I.													
Sums	2007·7	2006·2	2004·5	2080·5	2076·6	2067·7	2049·0	2022·0	1553·1	1327·6	1344·1	1357·9	2109·9
Means of 25 days ...	80·31	80·25	80·18	80·02	79·87	79·53	78·81	77·77	77·66	78·09	79·06	79·88	81·15
Diurnal changes ...	+0′·1	0′·0	0′·0	−0′·2	−0′·3	−0′·7	−1′·4	−2′·4	−2′·5	−2′·1	−1′·1	−0′·3	+0′·9
Diurnal oscillation...	2′·6	2′·5	2′·5	2′·3	2′·2	1′·8	1′·1	0′·1	0′·0	0′·4	1′·4	2′·2	3′·4
Diurnal declination .	49′ 19″ +0°	49′ 13″	49′ 13″	49′ 01″	48′ 55″	48′ 31″	47′ 49″	46′ 49″	46′ 43″	47′ 07″	48′ 07″	48′ 55″	50′ 07″
$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.													
Sums	1311·7	1308·8	1304·4	1351·3	1345·2	1336·4	1316·3	1288·6	937·1	846·0	864·2	880·8	1391·9
Means of 25 days ...	52·47	52·35	52·18	51·97	51·74	51·40	50·63	49·56	49·32	49·77	50·84	51·81	53·53
Diurnal changes ...	−0′·1	−0′·3	−0′·4	−0′·6	−0′·9	−1′·2	−2′·0	−3′·0	−3′·3	−2′·8	−1′·8	−0′·8	+0′·9
Diurnal oscillation...	3′·2	3′·0	2′·9	2′·7	2′·4	2′·1	1′·3	0′·3	0′·0	0′·5	1′·5	2′·5	4′·2
Diurnal declination .	49′ 44″ +0°	49′ 37″	49′ 31″	49′ 19″	49′ 01″	48′ 43″	47′ 55″	46′ 55″	46′ 37″	47′ 07″	48′ 07″	49′ 07″	50′ 49″

Observatory at Batavia.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000207=1'{\cdot}000207$. Declinometer No. I.													
Sums	1416·3	1417·6	1415·1	1977·6	1974·2	1968·3	1955·2	1921·1	1912·0	1923·0	1935·8	1958·1	1992·0
Means of 25 days ...	78·68	78·76	78·62	79·10	78·97	78·73	78·21	76·84	76·48	76·92	77·43	78·32	79·68
Diurnal changes ...	−0′·2	−0′·1	−0′·3	+0′·2	+0′·1	−0′·2	−0′·7	−2′·1	−2′·4	−2′·0	−1′·5	−0′·6	+0′·8
Diurnal oscillation...	2′·2	2′·3	2′·1	2′·6	2′·5	2′·2	1′·7	0′·3	0′·0	0′·4	0′·9	1′·8	3′·2
Diurnal declination .	48′ 55″ +0°	49′ 01″	48′ 49″	49′ 19″	49′ 13″	48′ 55″	48′ 25″	47′ 01″	46′ 43″	47′ 07″	47′ 37″	48′ 31″	49′ 55″

TABLE A.

Month of November, 1846. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E. (*Continued.*)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Declin.
Zero from the 9th to the 30th, 50·17. $\alpha = 0° 47' 07''$ East.														
	983·5	989·9	986·6	978·4	915·2	1010·8	1006·4	999·5	996·4	989·5	989·2	23438·7	994·0	
	54·64	54·99	54·81	54·36	53·84	53·20	52·97	52·60	52·44	52·08	52·06	1256·35	52·32	0° 49′ 13″
	+2′·3	+2′·7	+2′·5	+2′·1	+1′·5	+0′·9	+0′·7	+0′·3	+0′·1	−0′·2	−0′·2			
	4′·8	5′·2	5′·0	4′·6	4′·0	3′·4	3′·2	2′·8	2′·6	2′·3	2′·3			
	51′ 31″	51′ 51″	51′ 43″	51′ 19″	50′ 43″	50′ 07″	49′ 55″	49′ 31″	49′ 19″	49′ 01″	49′ 01″			

Month of December, 1846. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 31st, 78·11. $\alpha = 0° 47' 07''$ East.														
	2130·4	2136·0	2130·8	2121·7	2106·8	2015·1	2014·9	1529·7	1206·3	1202·7	1200·2	43801·4	2085·99	
	81·94	82·15	81·95	81·60	81·03	80·60	80·60	80·51	80·42	80·18	80·01	1923·57	80·22	0° 49′ 19″
	+1′·7	+1′·9	+1′·7	+1′·4	+0′·8	+0′·4	+0′·4	+0′·3	+0′·2	0′·0	−0′·2			
	4′·2	4′·4	4′·2	3′·9	3′·3	2′·9	2′·9	2′·8	2′·7	2′·5	2′·3			
	50′ 55″	51′ 07″	50′ 55″	50′ 37″	50′ 01″	49′ 37″	49′ 37″	49′ 31″	49′ 25″	49′ 13″	49′ 01″			
Zero from the 1st to the 31st, 49·77. $\alpha = 0° 47' 07''$ East.														
	1420·1	1429·9	1428·1	1423·1	1409·5	1341·2	1337·7	1011·0	792·0	787·9	782·1	28645·3	1368·87	
	54·62	55·00	54·93	54·73	54·21	53·65	53·51	53·21	52·80	52·53	52·14	1258·90	52·56	0° 49′ 55″
	+2′·0	+2′·4	+2′·3	+2′·1	+1′·6	+1′·0	+0′·9	+0′·6	+0′·2	−0′·1	−0′·5			
	5′·3	5′·7	5′·6	5′·4	4′·9	4′·3	4′·2	3′·9	3′·5	3′·2	2′·8			
	51′ 55″	52′ 19″	52′ 13″	52′ 01″	51′ 31″	50′ 55″	50′ 49″	50′ 31″	50′ 07″	49′ 49″	49′ 25″			

Month of January, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 31st, 76·9. $\alpha = 0° 47' 07''$ East.														
	2020·7	2025·8	2019·0	2003·4	1990·4	1987·2	1991·2	1587·1	1417·2	1413·7	1412 8	43634·8	1975·2	
	80·83	81·03	80·76	80·14	79·62	79·49	79·65	79·36	78·73	78·54	78·49	1893·38	78·90	0° 49′ 07″
	+1′·9	+2′·1	+1′·9	+1′·2	+0′·7	+0′·6	+0′·7	+0′·5	−0′·2	−0′·4	−0′·4			
	4′·3	4′·5	4′·3	3′·6	3′·1	3′·0	3′·1	2′·9	2′·2	2′·0	2′·0			
	51′ 01″	51′ 13″	51′ 01″	50′ 19″	49′ 49″	49′ 43″	49′ 49″	49′ 37″	48′ 55″	48′ 43″	48′ 43″			

TABLE A.

Observatory at Batavia.—Hourly observations made during the

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$\alpha\left(1+\frac{H}{F}\right)=1'\times 000139=1'000139$. Declinometer No. II.													
Sums	919·8	919·5	917·6	1258·2	1252·7	1244·0	1229·5	1195·8	1186·0	1198·6	1214·7	1235·6	1283·9
Means of 25 days	51·10	51·08	50·98	50·33	50·11	49·76	49·18	47·83	47·44	47·94	48·59	49·42	51·36
Diurnal changes	+0′·5	+0′·5	+0′·4	−0′·3	−0′·5	−0′·8	−1′·4	−2′·8	−3′·2	−2′·7	−2′·0	−1′·2	+0′·8
Diurnal oscillation	3′·7	3′·7	3′·6	2′·9	2′·7	2′·4	1′·8	0′·4	0′·0	0′·5	1′·2	2′·0	4′·0
Diurnal declination	50′ 19″ +0°	50′ 19″	50′ 13″	49′ 31″	49′ 13″	49′ 01″	48′ 25″	47′ 01″	46′ 37″	47′ 07″	47′ 49″	48′ 37″	50′ 37″

Observatory at Batavia.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times 1·000207=1'000207$. Declinometer No. I.													
Sums	1303·5	1304·9	1304·8	1971·4	1972·8	1973·8	1971·0	1940·3	1907·2	1892·2	1898·2	1928·2	1971·4
Means of 24 days	81·47	81·56	81·55	82·14	82·20	82·24	82·12	80·85	79·47	78·84	79·09	80·34	82·14
Diurnal changes	−0′·6	−0′·5	−0′·6	0′·0	+0′·1	+0′·1	0′·0	−1′·3	−2′·6	−3′·3	−3′·0	−1′·8	0′·0
Diurnal oscillation	2′·7	2′·8	2′·7	3′·3	3′·4	3′·4	3′·3	2′·0	0′·7	0′·0	0′·3	1′·5	3′·3
Diurnal declination	49′ 49″ +0°	49′ 55″	49′ 49″	50′ 25″	50′ 31″	50′ 31″	50′ 25″	49′ 07″	47′ 49″	47′ 07″	47′ 25″	48′ 37″	50′ 25″
$\alpha\left(1+\frac{H}{F}\right)=1'\times 1·000139=1'000139$. Declinometer No. II.													
Sums	791·4	795·2	790·0	1183·4	1184·7	1184·1	1178·2	1148·4	1109·5	1095·7	1105·9	1143·9	1193·5
Means of 24 days	49·46	49·70	49·38	49·31	49·36	49·34	49·09	47·85	46·23	45·65	46·08	47·66	49·73
Diurnal changes	−0′·1	+0′·1	−0′·2	−0′·3	−0′·2	−0′·3	−0′·5	−1′·8	−3′·4	−4′·0	−3′·5	−1′·9	+0′·1
Diurnal oscillation	3′·9	4′·1	3′·8	3′·7	3′·8	3′·7	3′·5	2′·2	0′·6	0′·0	0′·5	2′·1	4′·1
Diurnal declination	51′ 01″ +0°	51′ 13″	50′ 55″	50′ 49″	50′ 55″	50′ 49″	50′ 37″	49′ 19″	47′ 43″	47′ 07″	47′ 37″	49′ 13″	51′ 13″

Observatory at Batavia.—Hourly observations made during the

$\alpha\left(1+\frac{H}{F}\right)=1'\times 1·000207$. Declinometer No. I.													
Sums	.....	.....	.....	2244·0	2237·9	2232·2	2230·5	2213·1	2195·7	2197·8	2214·4	2232·0	2251·5
Means of 27 days	.....	.....	.....	83·11	82·89	82·67	82·61	81·97	81·32	81·40	82·02	82·67	83·39
Diurnal changes	.....	.....	.....	+0′·1	−0′·1	−0′·3	−0′·4	−1′·0	−1′·7	−1′·6	−1′·0	−0′·3	+0′·4
Diurnal oscillation	.....	.....	.....	1′·8	1′·6	1′·4	1′·3	0′·7	0′·0	1′·1	0′·7	1′·4	2′·1
Diurnal declination	.....	.....	.....	48′ 49″ +0°	48′ 37″	48′ 25″	48′ 19″	47′ 43″	47′ 01″	47′ 07″	47′ 43″	48′ 25″	49′ 07″

TABLE A.

Month of January, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E. (*Continued.*)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Declin.
Zero from the 1st to the 31st, 47·94. $\alpha = 0° 47' 07''$ East.														
	1313·1	1323·3	1321·4	1307·1	1295·0	1290·1	1291·3	1037·5	928·6	920·9	918·9	28003·1	1263·0	
	52·52	52·93	52·86	52·28	51·80	51·60	51·65	51·88	51·59	51·16	51·05	12164·4	50·64	0° 49′ 49″
	+1′·9	+2′·3	+2′·3	+1′·7	+1′·2	+1′·0	+1′·0	+1′·3	+1′·0	+0′·6	+0′·4			
	5′·1	5′·5	5′·5	4′·9	4′·4	4′·2	4′·2	4′·5	4′·2	3′·8	3′·6			
	51′ 31″	52′ 07″	52′ 07″	51′ 31″	51′ 01″	50′ 49″	50′ 49″	51′ 07″	50′ 49″	49′ 49″	49′ 37″			

Month of February, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 28th, 78·8. $\alpha = 0° 47' 07''$ East.														
	2010·0	2033·9	2035·7	2023·7	2002·5	1991·1	1990·5	1985·2	1897·2	1138·4	1139·6	43587·5	1972·5	
	83·75	84·75	84·82	84·32	83·44	82·96	82·94	82·72	82·49	81·31	81·40	1968·92	82·08	0° 50′ 25″
	+1′·6	+2′·6	+2′·7	+2′·2	+1′·3	+0′·9	+0′·8	+0′·6	+0′·4	−0′·8	−0′·7			
	4′·9	5′·9	6′·0	5′·5	4′·6	4′·2	4′·1	3′·9	3′·7	2′·5	2′·6			
	52′ 01″	53′ 01″	53′ 07″	52′ 37″	51′ 31″	51′ 19″	51′ 13″	51′ 01″	50′ 49″	49′ 37″	49′ 43″			
Zero from the 1st to the 28th, 45·65. $\alpha = 0° 47' 07''$ East.														
	1235·0	1262·4	1266·6	1256·0	1234·1	1223·6	1219·6	1213·4	1156·7	696·9	697·8	26366·0	1192·0	
	51·46	52·60	52·78	52·33	51·42	50·98	50·82	50·56	50·30	49·78	49·84	1191·71	49·65	0° 51′ 07″
	+1′·9	+3′·0	+3′·2	+2′·7	+1′·8	+1′·4	+1′·2	+1′·0	+0′·7	+0′·2	+0′·2			
	5′·9	7′·0	7′·2	6′·7	5′·8	5′·4	5′·2	5′·0	4′·7	4′·2	4′·2			
	53′ 01″	54′ 57″	54′ 19″	53′ 49″	52′ 55″	52′ 31″	52′ 19″	52′ 07″	51′ 49″	51′ 19″	51′ 19″			

Month of March, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 31st, 81·4. $\alpha = 0° 47' 07''$ East.														
	2263·7	2270·8	2267·7	2264·4	2258·6	2254·0	2252·8	2246·7	2148·3	.....	.....	42476·1	2240·1	
	83·84	84·10	83·99	83·87	83·65	83·48	83·44	83·21	82·63	.....	.....	1576·26	82·96	0° 48′ 43″
	+0′·8	+1′·1	+1′·0	+0′·9	+0′·6	+0′·5	+0′·4	+0′·2	−0′·4	.....	.....			
	2′·5	2′·8	2′·7	2′·6	2′·3	2′·2	2′·1	1′·9	1′·3	.....	.....			
	49′ 31″	49′ 49″	47′ 43″	49′ 37″	49′ 19″	49′ 13″	49′ 07″	48′ 55″	48′ 19″	.....	.....			

TABLE A.

Observatory at Batavia.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.				
Sums	1361·5	1354·4	1343·8	1339·0	1322·7	1299·9	1305·5	1321·2	1347·3	1370·4
Means of 27 days ...	50·43	50·16	49·77	49·59	48·99	48·14	48·35	48·93	49·90	50·76
Diurnal changes ...	0′·0	−0′·2	−0′·6	−0′·8	−1′·4	−2′·3	−2′·1	−1′·5	−0′·5	+0′·4
Diurnal oscillation...	2′·3	2′·1	1′·7	1′·5	0′·9	0′·0	0′·2	0′·8	1′·8	2′·7
Diurnal declination .	49′ 13″ +0°	49′ 01″	48′ 37″	48′ 25″	47′ 49″	46′ 55″	47′ 07″	47′ 43″	48′ 43″	49′ 57″

Observatory at Batavia.—Hourly observations made during the

						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.				
Sums	2157·6	2155·3	2150·7	2152·2	2138·6	2112·0	2006·4	2098·4	2118·0	2139·6
Means of 26 days ...	82·98	82·90	82·72	82·78	82·25	81·23	80·26	80·71	81·46	82·29
Diurnal changes.....	+0′·5	+0′·4	+0′·2	+0′·3	−0′·3	−1′·3	−2′·2	−1′·8	−1′·0	−0′·2
Diurnal oscillation...	2′·7	2′·6	2′·4	2′·5	1′·9	0′·9	0′·0	0′·4	1′·2	2′·0
Diurnal declination .	49′ 49″ +0°	49′ 43″	49′ 31″	49′ 37″	49′ 01″	48′ 01″	47′ 07″	47′ 31″	48′ 19″	49′ 07″
						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.				
Sums	1305·6	1302·3	1296·5	1295·8	1283·9	1254·3	1184·3	1244·8	1265·2	1293·1
Means of 26 days ...	50·22	50·09	49·87	49·84	49·38	48·24	47·37	47·88	48·66	49·73
Diurnal changes ...	+0′·3	+0′·2	0′·0	−0′·1	−0′·5	−1′·7	−2′·5	−2′·0	−1′·2	−0′·2
Diurnal oscillation...	2′·8	2′·7	2′·5	2′·4	2′·0	0′·8	0′·0	0′·5	1′·3	2′·3
Diurnal declination .	49′ 55″ +0°	49′ 49″	49′ 37″	49′ 31″	49′ 07″	47′ 55″	47′ 07″	47′ 37″	48′ 25″	49′ 25″

Observatory at Batavia.—Hourly observations made during the

						$\alpha\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.				
Sums	2189·2	2190·6	2192·6	2202·7	2203·6	2178·1	1826·7	2147·6	2148·3	2149·9
Means of 26 days ...	84·20	84·25	84·33	84·72	84·75	83·77	83·03	82·60	82·63	82·69
Diurnal changes ...	+0′·3	+0′·3	+0′·4	+0′·8	+0′·8	−0′·1	−0′·9	−1′·3	−1′·3	−1′·2
Diurnal oscillation...	1′·6	1′·6	1′·7	2′·1	2′·1	1′·2	0′·4	0′·0	0′·0	0′·1
Diurnal declination .	43′ 19″ +0°	48′ 19″	48′ 25″	48′ 49″	48′ 49″	47′ 55″	47′ 07″	46′ 43″	46′ 43″	46′ 49″

TABLE A

Month of March, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E. (*Continued.*)

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 1st to the 31st, 48·35. $\alpha = 0° 47' 07''$ East.											
1388·7	1397·9	1397·5	1397·8	1394·8	1389·6	1387·1	1379·3	1307·8	25806·2	1360·8	
51·43	51·77	51·76	51·77	51·66	51·47	51·37	51·09	50·30	957·64	50·40	0° 49′ 13″
+1′·0	+1′·4	+1′·4	+1′·4	+1′·3	+1′·1	+1′·0	+0′·7	−0′·1			
3′·3	3′·7	3′·7	3′·7	3′·6	3′·4	3′·3	3′·0	2′·2			
50′ 13″	50′ 37″	50′ 37″	50′ 37″	50′ 31″	50′ 19″	50′ 13″	49′ 55″	49′ 07″			

Month of April, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 30th, 80·26. $\alpha = 0° 47' 07''$ East.											
2155·4	2166·5	2090·6	2169·4	2165·1	1664·1	1658·6	1651·3	1647·3	38597·1	2144·3	
82·90	83·33	83·62	83·44	83·27	83·21	82·93	82·57	82·37	1567·22	82·47	0° 49′ 19″
+0′·4	+0′·8	+1′·1	+0′·9	+0′·8	+0′·7	+0′·4	+0′·1	−0′·1			
2′·6	3′·0	3′·3	3′·1	3′·0	2′·9	2′·6	2′·3	2′·1			
49′ 31″	50′ 07″	50′ 25″	50′ 13″	50′ 07″	50′ 01″	49′ 43″	49′ 25″	49′ 13″			
Zero from the 1st to the 30th, 47·37. $\alpha = 0° 47' 07''$ East.											
1314·3	1329·5	1287·6	1335·4	1332·8	1024·3	1017·0	1009·4	1002·5	23378·6	1298·8	
50·55	51·13	51·50	51·36	51·26	51·22	50·85	50·47	50·13	949·75	49·95	0° 49′ 37″
+0′·6	+1′·2	+1′·6	+1′·5	+1′·4	+1′·3	+0′·9	+0′·6	+0′·2			
3′·1	3′·7	4′·1	4′·0	3′·9	3′·8	3′·4	3′·1	2′·7			
50′ 13″	50′ 49″	51′ 13″	51′ 07″	51′ 01″	50′ 55″	50′ 31″	50′ 13″	49′ 49″			

Month of May, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 31st, 83·03. $\alpha = 0° 47' 07''$ East.											
2167·2	2188·0	1865·2	2214·4	2208·4	2107·3	2013·7	2003·0	1996·6	40193·1	2181·7	
83·35	84·15	84·78	85·17	84·94	84·29	83·90	83·46	83·19	1594·20	83·91	0° 48′ 01″
−0′·6	+0′·2	+0′·9	+1′·3	+1′·0	+0′·4	0′·0	−0′·4	−0′·7			
0′·7	1′·5	2′·2	2′·6	2′·3	1′·7	1′·3	0′·9	0′·6			
47′ 25″	48′ 13″	48′ 55″	49′ 19″	49′ 01″	48′ 25″	48′ 01″	47′ 37″	47′ 19″			

TABLE A.

Observatory at Batavia.—Hourly observations made during the

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
					$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.					
Sums	1318·8	1319·5	1319·3	1327·7	1326·9	1305·1	1089·0	1277·9	1280·0	1289·4
Means of 26 days	50·72	50·75	50·74	51·07	51·03	50·20	49·50	49·15	49·23	49·59
Diurnal changes	0′·0	0′·0	0′·0	+0′·4	+0′·3	−0′·5	−1′·2	−1′·6	−1′·5	−1′·1
Diurnal oscillation	1′·6	1′·6	1′·6	2′·0	1′·9	1′·1	0′·4	0′·0	0′·1	0′·5
Diurnal declination	48′ 19″ +0°	48′ 19″	48′ 19″	48′ 43″	48′ 37″	47′ 49″	47′ 07″	46′ 43″	46′ 49″	47′ 13″

Observatory at Batavia.—Hourly observations made during the

					$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000158=1'{\cdot}000158$. Declinometer No. I.					
Sums	2164·8	2167·1	2169·6	2094·5	2110·8	2093·2	1742·3	2063·1	2142·8	2145·2
Means of 26 days	83·26	83·35	83·45	83·78	84·43	83·73	82·97	82·52	82·42	82·51
Diurnal changes	0′·0	+0′·1	+0′·2	+0′·5	+1′·1	+0′·4	−0′·3	−0′·3	−0′·9	−0′·8
Diurnal oscillation	0′·9	1′·0	1′·1	1′·4	2′·0	1′·3	0′·6	0′·6	0′·0	0′·1
Diurnal declination	47′ 25″ +0°	47′ 31″	47′ 37″	47′ 55″	48′ 31″	47′ 49″	47′ 07″	47′ 07″	46′ 31″	46′ 37″
					$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000139=1'{\cdot}000139$. Declinometer No. II.					
Sums	1338·9	1342·2	1341·8	1298·3	1311·7	1296·3	1075·0	1273·7	1326·2	1332·4
Means of 26 days	51·50	51·62	51·61	51·93	52·47	51·85	51·19	50·95	51·01	51·25
Diurnal changes	−0′·6	−0′·5	−0′·5	−0′·2	+0′·4	−0′·3	−0′·9	−1′·2	−1′·1	−0′·9
Diurnal oscillation	0′·6	0′·7	0′·7	1′·0	1′·6	0′·9	0′·3	0′·0	0′·1	0′·3
Diurnal declination	47′ 25″ +0°	47′ 31″	47′ 31″	47′ 49″	48′ 25″	47′ 43″	47′ 07″	46′ 49″	46′ 55″	47′ 01″

Observatory at Cocos Island.—Hourly observations made during the Month of

					$\alpha\left(1+\frac{H}{F}\right)=1'\times 1{\cdot}000305=1'{\cdot}000305$. Declinometer No. I.					
Sums	2366·0	2370·4	2369·5	2380·2	2368·1	2324·8	2287·9	2277·4	2287·6	2316·2
Means of 27 days	87·63	87·79	87·76	88·16	87·71	86·10	84·74	84·35	84·73	85·79
Diurnal changes	+0′·53	+0′·69	+0′·66	+1′·06	+0′·61	−1′·00	−2′·36	−2′·75	−2′·37	−1′·21
Diurnal oscillation	3′·28	3′·44	3′·41	3′·81	3′·36	1′·75	0′·39	0′·00	0′·38	1′·44
Diurnal declination	07′ 49″ −1°	07′ 39″	07′ 41″	07′ 17″	07′ 44″	09′ 20″	10′ 42″	11′ 05″	10′ 43″	9′ 39″

TABLE A.

Month of May, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E. (*Continued.*)

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from the 1st to the 31st, 49·5. $\alpha = 0° 47' 07''$ East.											
1311·8	1332·5	1147·4	1365·6	1357·8	1287·5	1225·7	1213·6	1205·6	24301·1	1318·6	
50·45	51·25	52·15	52·52	52·22	51·50	51·07	50·57	50·23	963·94	50·73	0° 48′ 19″
−0′·3	+0′·5	+1′·4	+1′·8	+1′·5	+0′·8	+0′·4	−0′·1	−0′·5			
1′·3	2′·1	3′·0	3′·4	3′·1	2′·4	2′·0	1′·5	1′·1			
48′ 02″	48′ 49″	49′ 43″	50′ 07″	49′ 49″	49′ 07″	48′ 43″	48′ 13″	47′ 49″			

Month of June, 1847. Latitude 6° 09′ 52″ S. Longitude 106° 58′ 00″ E.

Zero from the 1st to the 30th, 32·97. $\alpha = 0° 47' 07''$ East.											
2152·3	2081·7	1765·2	2104·0	2009·6	1912·3	1741·3	1736·9	1731·3	38128·0	2165·6	
82·78	83·27	84·06	84·16	83·73	83·14	82·92	82·71	82·44	1581·63	83·25	
−0′·5	0′·0	+0′·8	+0′·9	+0′·4	−0′·2	−0′·4	−0′·6	−0′·9			
0′·4	0′·9	1′·7	1′·8	1′·3	0′·7	0′·5	0′·3	0′·0			
46′ 55″	47′ 25″	48′ 13″	48′ 19″	47′ 49″	47′ 13″	47′ 01″	46′ 49″	46′ 31″			
Zero from the 1st to the 30th, 51·19. $\alpha = 0° 47' 07''$ East.											
1347·0	1315·9	1124·6	1344·8	1281·7	1210·6	1101·6	1094·6	1088·3	23845·6	1352·8	
51·81	52·64	53·55	53·79	53·40	52·63	52·46	52·12	51·82	989·60	52·06	0° 48′ 01″
−0′·3	+0′·5	+1′·4	+1′·7	+1′·3	+0′·5	+0′·4	0′·0	−0′·3			
0′·9	1′·7	2′·6	2′·9	2′·5	1′·7	1′·6	1′·2	0′·9			
47′ 43″	48′ 31″	49′ 25″	49′ 43″	49′ 19″	48′ 31″	48′ 25″	48′ 01″	47′ 43″			

August and September, 1848. Latitude 12° 05′ 38″ S. Longitude 96° 50′ 30″ E.

Zero from August the 28th to September the 27th, 84·74. $\alpha = 1° 10' 42''$ West.											
2350·1	2377·8	2392·4	2394·2	2379·4	2364·3	2366·6	2358·3	2352·2	45726·8	2351·6	
87·04	88·07	88·61	88·67	88·13	87·57	87·65	87·34	87·12	1654·96	87·10	1° 08′ 28″
−0′·06	+0′·97	+1′·51	+1′·57	+1′·03	+0′·47	+0′·55	+0′·24	+0′·22			
2′·69	3′·72	4′·26	4′·82	3′·78	3′·22	3′·30	2′·99	2′·97			
08′ 24″	07′ 22″	06′ 50″	06′ 46″	07′ 19″	07′ 52″	07′ 47″	08′ 06″	08′ 07″			

TABLE A.

Observatory at Cocos Island.—Hourly observations made during the Month of August

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$a\left(1+\frac{H}{F}\right)=1'\times1{\cdot}000371=1'{\cdot}000371$. Declinometer No. II.										
Sums	1243·8	1247·0	1244·7	1255·6	1242·0	1200·2	1127·5	1175·1	1194·9	1229·5
Means of 27 days	46·07	46·19	46·10	46·50	46·00	44·45	43·37	43·52	44·26	45·54
Diurnal changes	0'·00	+0'·12	+0'·03	+0'·43	−0'·07	−1'·62	−2'·70	−2'·55	−1'·81	−0'·53
Diurnal oscillation	2'·70	2'·82	2'·73	3'·13	2'·63	1'·08	0'·00	0'·15	0'·89	2'·17
Diurnal declination	08′ 00″ −1°	07′ 53″	07′ 58″	07′ 34″	08′ 04″	09′ 37″	10′ 42″	10′ 33″	09′ 49″	08′ 32″
$a\left(1+\frac{H}{F}\right)$ 1'·0047 × 1·00037 = 1'·004. Declinometer No. III.										
Sums	2652·1	2654·5	2755·9	2766·3	2753·7	2610·4	2679·2	2675·7	2695·3	2731·2
Means of 27 days	102·00	102·10	102·07	102·46	101·99	100·40	99·23	99·10	99·83	101·16
Diurnal changes	+0'·01	+0'·11	+0'·08	+0'·47	0'·00	−1'·59	−2'·76	−2'·89	−2'·16	−0'·83
Diurnal oscillation	2'·90	3'·00	2'·97	3'·36	2'·89	1'·30	0'·13	0'·00	0'·73	2'·06
Diurnal declination	07′ 56″ −1°	07′ 50″	7′ 52″	7′ 28″	7′ 56″	9′ 32″	10′ 42″	10′ 50″	9′ 12″	8′ 46″

TABLE A.

and September, 1848. Latitude 12° 05′ 38″ S. Longitude 96° 50′ 30″ E. (*Continued.*)

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Declin.
Zero from August the 28th to September the 27th, 43·37. $\alpha = 1° 10' 42''$ West.											
1214·3	1288·0	1298·3	1293·8	1276·5	1254·8	1198·2	1241·2	1232·8	24048·3	1242·6	
46·70	47·70	48·09	47·92	47·28	46·47	46·08	45·97	45·66	873·87	46·07	1° 08′ 00″
+0′·63	+1′·63	+2′·02	+1′·85	+1′·21	+0′·40	+0′·01	−0′·10	−0′·41			
3′·33	4′·33	4′·72	4′·55	3′·91	3′·10	2′·71	2′·60	2′·29			
07′ 22″	06′ 22″	05′ 59″	06′ 09″	06′ 47″	07′ 36″	07′ 59″	08′ 06″	08′ 25″			
Zero from August the 28th to September the 27th, 99·23. $\alpha = 1° 10' 42''$ West.											
2769·1	2796·3	2811·1	2811·1	2794·6	2773·3	2772·1	2760·7	2752·5	53240·8	2753·4	
102·56	103·57	104·11	104·11	103·50	102·71	102·67	102·25	101·94	1937·76	101·99	1° 07′ 56″
+0′·57	+1′·58	+2′·12	+2′·12	+1′·51	+0′·72	+0′·68	+0′·26	−0′·05			
3′·46	4′·47	5′·01	5′·01	4′·40	3′·61	3′·57	3′·15	2′·84			
7′ 22″	6′ 22″	5′ 49″	5′ 49″	6′ 26″	7′ 13″	7′ 16″	7′ 41″	7′ 59″			

Oscillation of the Horizontal Intensity at various Stations in the Eastern

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Moulmein	.....	.....	.....	0·00	0·30	0·03	0·55	1·80	5·89	10·19	17·09
Madras	.....	.....	.....	0·28	0·26	0·37	0·56	2·23	5·28	9·73	12·55
Nicobar	.....	.....	.....	2·50	2·86	3·44	4·12	3·28	6·00	9·90	14·46
Sambooanga	.....	.....	.....	0·02	0·00	0·10	0·68	2·55	4·49	6·57	9·59
Penang	.....	.....	.....	0·38	0·52	0·00	0·66	1·90	6·40	10·62	13·74
Pulo Dinding	.....	.....	.....	0·00	0·20	0·40	0·85	2·55	5·35	8·45	11·35
Sarawak	0·35	0·51	0·70	0·80	0·92	1·10	1·47	2·29	3·67	5·31	6·19
Keemah	.....	.....	.....	0·00	0·12	0·21	0·71	2·12	4·35	6·69	8·64
Pulo Peesang	.....	.....	.....	.....	.....	3·23	0·20	1·44	3·00	6·02	6·90
Singapore	.....	.....	.....	1·53	1·49	1·33	1·84	2·25	3·63	4·63	5·91
Carimon	.....	.....	.....	.....	.....	0·46	1·07	2·47	4·25	6·32	6·65
Bowaya	.....	.....	.....	.....	.....	2·28	3·15	4·81	6·41	8·31	8·48
Padang	.....	.....	.....	1·63	1·56	1·67	2·12	3·11	4·60	6·21	7·56
Bencoolen	.....	.....	.....	1·30	1·30	1·20	1·30	4·67	4·38	6·18	7·66
Batavia, Winter	0·51	0·41	0·55	0·33	0·60	0·58	0·76	1·59	2·51	4·18	5·13
Batavia, Spring	.....	.....	.....	0·00	0·18	0·45	0·93	1·88	3·47	4·68	5·78
Cocos	.....	.....	.....	0·98	1·37	1·60	1·81	3·34	4·51	5·79	6·53
Singapore, No. II.	.....	.....	.....	0·81	0·70	0·57	0·93	1·25	3·73	5·60	8·07

Oscillation of the Horizontal Intensity at Batavia,

November .....1846...	0·25	0·07	0·41	0·00	0·14	0·36	0·60	1·56	2·83	4·32	5·16
December	0·88	0·85	0·83	0·67	0·74	0·91	1·08	2·05	3·06	4·18	4·72
January .....1847...	0·45	0·26	0·43	0·55	0·73	0·88	0·97	1·88	2·01	4·59	5·95
February	1·38	1·40	1·43	1·02	0·92	1·11	1·31	1·81	3·06	4·57	5·63
Sums	2·96	2·58	3·10	2·24	2·53	3·26	3·96	7·30	10·96	17·66	21·46
Means	0·74	0·64	0·78	0·56	0·63	0·81	0·99	1·82	2·74	4·41	5·36
Oscillation	0·51	0·41	0·55	0·33	0·60	0·58	0·76	1·59	2·51	4·18	5·13

Oscillation of the Horizontal Intensity at Batavia,

March .....1847...	.....	.....	.....	0·00	0·25	0·34	0·51	1·10	2·88	4·35	5·21
April	.....	.....	.....	0·56	0·54	0·60	1·28	2·57	3·95	4·72	6·88
May	.....	.....	.....	0·75	0·93	1·15	1·48	2·50	4·20	5·48	6·01
June	.....	.....	.....	0·00	0·34	1·03	1·79	2·68	4·17	5·49	6·33
Sums	.....	.....	.....	1·31	2·06	3·12	5·06	8·85	15·20	20·04	24·43
Means	.....	.....	.....	0·33	0·51	0·78	1·26	2·21	3·80	5·01	6·11
Oscillation	.....	.....	.....	0·00	0·18	0·45	0·93	1·88	3·47	4·68	5·78

Oscillation of the Horizontal Intensity at Sarawak

June .....1846...	0·49	0·68	0·78	0·98	0·90	1·03	1·50	2·53	3·84	5·44	6·28
July	0·51	0·84	1·07	1·05	1·12	1·43	1·79	2·58	4·33	5·80	6·89
August	0·55	0·51	0·77	0·88	1·25	1·35	1·64	2·28	3·35	5·21	5·90
Sums	1·55	2·03	2·62	2·91	3·27	3·81	4·93	7·39	11·52	16·45	19·07
Means	0·52	0·68	0·87	0·97	1·09	1·27	1·64	2·46	3·84	5·48	6·36
Oscillation	0·35	0·51	0·70	0·80	0·92	1·10	1·47	2·29	3·67	5·31	6·19

Archipelago.—In Scale Divisions. $k = \cdot 000240$.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
21·29	23·43	20·59	20·84	18·55	15·76	12·37	8·30	6·67	4·55	3·06	.....	.....	10·06
14·15	14·33	12·49	9·38	7·41	5·64	4·51	2·42	0·97	0·16	0·00	.....	.....	5·41
16·24	16·98	18·20	13·98	8·32	7·06	5·32	3·36	1·48	0·80	0·00	.....	.....	7·49
11·27	12·59	12·44	9·57	6·01	3·53	2·27	2·42	1·45	1·42	1·97	.....	.....	4·68
16·56	12·88	9·70	5·22	3·24	3·84	3·64	3·44	3·10	3·14	3·48	.....	.....	5·39
12·55	11·75	7·75	4·85	3·05	1·35	1·45	2·15	1·20	0·25	1·50	.....	.....	4·05
6·38	5·94	4·81	3·77	2·05	1·26	0·69	0·01	0·18	0·05	0·00	0·06	0·20	2·03
9·65	9·79	8·74	7·83	5·79	3·96	2·72	2·05	2·30	2·26	2·49	.....	.....	4·23
6·06	5·20	3·36	2·04	1·86	2·22	1·12	2·18	2·38	1·48	0·00	.....	.....	2·99
5·80	4·97	3·83	2·94	2·60	1·71	1·33	0·29	0·00	0·27	0·60	.....	.....	2·48
6·36	2·96	2·22	0·90	0·22	0·00	0·27	0·33	0·14	0·04	.....	.....	.....	2·17
7·15	4·94	3·33	2·80	2·00	0·00	0·75	0·80	0·43	0·08	.....	.....	.....	3·60
7·83	7·33	5·96	4·16	2·82	1·50	1·19	1·32	0·61	0·00	0·16	.....	.....	3·23
7·92	7·70	5·70	4·90	3·00	2·36	2·12	1·54	1·14	0·38	0·00	.....	.....	3·46
5·51	5·01	4·20	3·29	2·20	1·24	0·64	0·24	0·12	0·00	0·00	0·27	0·23	1·66
6·27	5·94	4·86	3·22	1·70	0·86	0·34	0·18	0·06	0·13	0·66	.....	.....	2·19
7·32	7·63	6·53	4·78	3·29	2·02	1·21	0·73	0·49	0·02	0·00	.....	.....	3·15
9·33	7·13	5·73	3·85	2·85	2·02	1·34	0·30	0·00	0·02	0·17	.....	.....	2·87

Java, Eastern Archipelago.

5·21	4·81	3·80	3·21	2·20	1·41	0·72	0·40	0·60	0·70	0·46	0·23	0·17	1·66
4·93	4·59	3·47	2·51	1·56	1·04	0·56	0·35	0·18	0·00	0·07	0·45	0·44	1·66
6·54	5·54	5·24	4·32	2·93	1·82	1·24	0·61	0·29	0·22	0·19	0·00	0·11	1·99
6·27	6·01	5·20	4·05	3·02	1·63	0·96	0·53	0·35	0·00	0·21	1·31	1·11	2·26
22·95	20·95	17·71	14·09	9·71	5·90	3·48	1·89	1·42	0·92	0·93	1·99	1·83	7·57
5·74	5·24	4·43	3·52	2·43	1·47	0·87	0·47	0·35	0·23	0·23	0·50	0·46	1·89
5·51	5·01	4·20	3·29	2·20	1·24	0·64	0·24	0·12	0·00	0·00	0·27	0·23	1·66

Java, Eastern Archipelago.

5·76	6·10	5·42	3·96	2·44	1·34	0·75	0·40	0·25	0·05	0·54	.....	.....	2·19
7·52	6·70	5·21	3·25	1·28	0·55	0·29	0·00	0·04	0·38	0·74	.....	.....	2·51
6·61	6·35	4·96	3·34	1·77	0·95	0·22	0·00	0·30	0·29	0·61	.....	.....	2·52
6·50	5·93	5·16	3·67	2·62	1·92	1·42	1·66	0·98	1·14	2·07	.....	.....	2·88
26·39	25·08	20·75	14·22	8·11	4·76	2·68	2·06	1·57	1·86	3·96	.....	.....	10·10
6·60	6·27	5·19	3·55	2·03	1·19	0·67	0·51	0·39	0·46	0·99	.....	.....	2·52
6·27	5·94	4·86	3·22	1·70	0·86	0·34	0·18	0·06	0·13	0·66	.....	.....	2·19

in Borneo, Eastern Archipelago.

6·49	6·00	4·95	3·66	2·28	1·21	0·32	0·02	0·15	0·00	0·03	0·23	0·32	2·09
7·08	6·55	5·06	4·17	2·49	1·51	1·21	0·00	0·20	0·20	0·44	0·45	0·56	2·39
6·08	5·79	4·92	3·98	1·69	1·58	1·06	0·51	0·71	0·47	0·03	0·00	0·22	2·12
19·65	18·34	14·93	11·81	6·66	4·30	2·59	0·53	1·06	0·67	0·50	0·68	1·10	6·60
6·55	6·11	4·98	3·94	2·22	1·43	0·86	0·18	0·35	0·22	0·17	0·23	0·37	2·20
6·38	5·94	4·81	3·77	2·05	1·26	0·69	0·01	0·18	0·05	0·00	0·06	0·20	2·03

Oscillation of the Horizontal Intensity at Padang in Sumatra,

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
October .....1847.....	.....	.....	.....	3·81	3·61	3·28	3·82	4·76	6·76	8·88	11·06
November	.....	.....	.....	1·02	0·89	1·09	1·52	2·88	4·17	5·68	6·28
December	.....	.....	.....	0·00	0·37	0·93	1·17	2·28	3·84	4·53	5·83
January .....1848.....	.....	.....	.....	2·36	2·00	2·04	2·62	3·17	4·26	6·40	7·70
Sums	.....	.....	.....	7·18	6·87	7·34	9·13	13·09	19·03	25·49	30·87
Means	.....	.....	.....	1·79	1·72	1·83	2·28	3·27	4·76	6·37	7·72
Oscillation	.....	.....	.....	1·63	1·56	1·67	2·12	3·11	4·60	6·21	7·56

Oscillation of the Horizontal Intensity at Singapore,

November ...1848.....	.....	.....	.....	2·41	2·28	2·03	2·41	2·36	4·61	5·25	6·48
December	.....	.....	.....	0·65	0·71	0·64	1·27	2·14	2·65	4·01	5·35
Means	.....	.....	.....	1·53	1·49	1·33	1·84	2·25	3·63	4·63	5·91
Oscillation	.....	.....	.....	1·53	1·49	1·33	1·84	2·25	3·63	4·63	5·91

Oscillation of the Horizontal Intensity at Singapore,

November .....1848...	.....	.....	.....	1·95	1·59	1·41	1·81	1·96	5·03	6·55	9·19
December	.....	.....	.....	0·00	0·14	0·05	0·38	0·86	2·76	4·98	7·28
Sums	.....	.....	.....	1·95	1·73	1·56	2·19	2·82	7·79	11·53	16·47
Means	.....	.....	.....	0·97	0·86	0·73	1·09	1·41	3·89	5·76	8·23
Oscillation	.....	.....	.....	0·81	0·70	0·57	0·93	1·25	3·73	5·60	8·07

Mean Hourly Oscillation of the Horizontal Intensity

December	0·18	0·35	0·49	0·73	0·75	0·76	1·11	1·91	3·20	4·56	5·70
January	0·34	0·11	0·42	0·36	0·50	0·61	1·12	1·72	2·92	4·30	5·81
February	0·01	0·09	0·29	0·29	0·50	0·59	0·74	1·36	2·75	4·82	6·14
Sums	0·53	0·55	1·20	1·38	1·75	1·96	2·97	4·99	8·87	13·68	17·65
Means	0·18	0·18	0·40	0·46	0·58	0·65	0·99	1·66	2·96	4·56	5·88
Oscillation	0·13	0·13	0·35	0·41	0·53	0·60	0·94	1·61	2·91	4·51	5·83

Mean Hourly Oscillation of the Horizontal Intensity

March	0·23	0·39	0·37	0·45	0·57	0·59	0·61	1·43	3·13	5·07	6·56
April	0·00	0·20	0·48	0·61	0·73	0·82	1·12	2·35	4·28	6·34	8·12
May	0·16	0·21	0·21	0·19	0·31	0·49	1·21	2·32	4·03	5·49	6·52
Sums	0·39	0·80	1·06	1·25	1·61	1·90	2·94	6·10	11·44	16·90	21·20
Means	0·13	0·27	0·35	0·42	0·54	0·63	0·98	2·03	3·81	5·63	7·07
Oscillation	0·07	0·21	0·29	0·36	0·48	0·57	0·92	1·97	3·75	5·57	7·01

Mean Hourly Oscillation of the Horizontal Intensity

June	0·03	0·07	0·17	0·18	0·22	0·35	1·00	2·06	3·46	4·84	5·84
July	0·12	0·22	0·32	0·21	0·49	0·72	1·33	2·37	3·83	5·12	5·94
August	0·19	0·53	0·57	0·57	0·81	0·89	1·52	2·54	4·19	5·43	6·57
Sums	0·34	0·82	1·06	0·96	1·52	1·96	3·85	6·97	11·48	15·39	18·35
Means	0·11	0·27	0·35	0·32	0·51	0·65	1·28	2·32	3·83	5·13	6·12
Oscillation	0·08	0·24	0·32	0·29	0·48	0·62	1·25	2·29	3·80	5·10	6·09

Eastern Archipelago. In Scale Divisions $k = \cdot 000240$.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
12·26	11·81	9·68	6·63	4·26	2·12	2·19	3·74	1·61	0·00	0·46	.....	.....	5·31
5·86	5·22	4·16	2·87	2·96	1·22	0·74	0·41	0·19	0·00	0·06	.....	.....	2·48
6·12	5·72	4·65	3·46	2·41	1·64	1·30	0·58	0·60	0·42	0·78	.....	.....	2·45
7·72	7·21	6·00	4·31	2·29	1·65	1·17	1·18	0·68	0·24	0·00	.....	.....	3·32
31·96	29·96	24·49	17·27	11·92	6·63	5·40	5·91	3·08	0·66	1·30	.....	.....	13·56
7·99	7·49	6·12	4·32	2·98	1·66	1·35	1·48	0·77	0·16	0·32	.....	.....	3·39
7·83	7·33	5·96	4·16	2·82	1·50	1·19	1·32	0·61	0·00	0·16	.....	.....	3·23

Eastern Archipelago. Portable Bifilar $k = \cdot 000240$.

6·09	4·89	3·76	2·61	2·53	2·16	1·57	0·31	0·00	0·47	0·78	.....	.....	2·79
5·51	5·06	3·90	3·27	2·68	1·27	1·10	0·27	0·00	0·07	0·43	.....	.....	2·17
5·80	4·97	3·83	2·94	2·60	1·71	1·33	0·29	0·00	0·27	0·60	.....	.....	2·48
5·80	4·97	3·83	2·94	2·60	1·71	1·33	0·29	0·00	0·27	0·60	.....	.....	2·48

Eastern Archipelago. Observatory Bifilar $k = \cdot 000197$.

9·13	7·45	6·32	4·17	3·35	2·88	2·08	0·60	0·00	0·37	0·66	.....	.....	3·62
7·65	7·14	5·47	3·86	2·67	1·49	0·93	0·32	0·32	0·00	0·00	.....	.....	2·44
16·78	14·59	11·79	8·03	6·02	4·37	3·01	0·92	0·32	0·37	0·66	.....	.....	6·06
8·39	7·29	5·89	4·01	3·01	2·18	1·50	0·46	0·16	0·18	0·33	.....	.....	3·03
9·23	7·13	5·73	3·85	2·85	2·02	1·34	0·30	0·00	0·02	0·17	.....	.....	2·87

in the Winter Months of 1843, 1844, 1845.

5·57	4·83	3·87	2·83	2·00	1·60	1·26	0·69	0·26	0·00	0·02	0·03	0·09	1·79
5·97	5·27	4·11	3·00	2·03	1·66	1·27	0·86	0·50	0·50	0·17	0·12	0·00	1·83
6·64	6·06	4·86	3·68	2·57	1·72	1·50	0·84	0·48	0·23	0·05	0·00	0·10	1·90
18·18	16·16	12·84	9·51	6·60	4·98	4·03	2·39	1·24	0·73	0·24	0·15	0·19	5·52
6·06	5·39	4·28	3·17	2·20	1·66	1·34	0·80	0·41	0·24	0·08	0·05	0·06	1·84
6·01	5·34	4·23	3·12	2·15	1·61	1·29	0·75	0·36	0·19	0·03	0·00	0·01	1·79

in the Spring Months of 1843, 1844, 1845.

7·09	6·71	5·11	3·45	2·21	1·62	1·28	0·80	0·42	0·19	0·05	0·00	0·08	2·03
8·19	7·25	5·65	3·96	2·47	1·76	1·27	0·95	0·69	0·29	0·18	0·24	0·10	2·45
6·72	6·00	4·71	3·56	2·20	1·21	0·72	0·67	0·52	0·41	0·22	0·20	0·00	2·04
22·00	19·96	15·47	10·97	6·88	4·59	3·27	2·42	1·63	0·89	0·45	0·44	0·18	6·52
7·33	6·65	5·16	3·66	2·29	1·53	1·09	0·81	0·54	0·30	0·15	0·15	0·06	2·17
7·27	6·59	5·10	3·60	2·23	1·47	1·03	0·75	0·48	0·24	0·09	0·09	0·00	2·11

in the Summer Months of 1843, 1844, 1845.

6·06	5·56	4·46	3·17	1·71	0·80	0·24	0·19	0·20	0·06	0·02	0·02	0·00	1·70
6·28	5·79	4·76	3·41	2·06	1·21	0·83	0·36	0·37	0·20	0·20	0·08	0·00	1·95
6·56	5·81	4·79	3·31	2·09	1·10	0·67	0·60	0·26	0·30	0·00	0·08	0·08	2·07
18·90	17·16	14·01	9·89	5·86	3·11	1·74	1·15	0·83	0·56	0·22	0·18	0·08	5·72
6·30	5·72	4·67	3·30	1·95	1·04	0·58	0·38	0·28	0·19	0·07	0·06	0·03	1·91
6·27	5·69	4·64	3·27	1·92	1·01	0·55	0·35	0·25	0·16	0·04	0·03	0·00	1·88

Mean Hourly Oscillation of the Horizontal Intensity in the

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
September	0·09	0·39	0·71	0·89	0·94	0·85	1·23	2·44	4·37	5·95	6·80
October	0·28	0·61	0·62	0·87	0·98	0·92	0·99	1·99	3·91	5·83	7·02
December	0·11	0·30	0·41	0·73	0·66	0·69	0·87	1·81	3·36	4·88	5·95
Sums	0·48	1·30	1·74	2·49	2·58	2·46	3·09	6·24	11·64	16·66	19·77
Means	0·16	0·43	0·58	0·83	0·86	0·82	1·03	2·08	3·88	5·55	6·59
Oscillation	0·15	0·42	0·57	0·82	0·85	0·81	1·02	2·07	3·87	5·54	6·58

Mean Hourly Oscillation of the Horizontal Intensity

Winter	0·13	0·13	0·35	0·41	0·53	0·60	0·94	1·61	2·91	4·51	5·83
Spring	0·07	0·21	0·29	0·36	0·48	0·57	0·92	1·97	3·75	5·57	7·01
Summer	0·08	0·24	0·32	0·29	0·48	0·62	1·25	2·29	3·80	5·10	6·09
Autumn	0·15	0·42	0·57	0·82	0·85	0·81	1·02	2·07	3·87	5·54	6·58
Sums	0·43	1·00	1·53	1·88	2·34	2·60	4·13	7·94	14·33	20·72	25·51
Means	0·11	0·25	0·38	0·47	0·58	0·65	1·03	1·98	3·58	5·18	6·38
Oscillation	0·09	0·23	0·36	0·45	0·56	0·63	1·01	1·96	3·56	5·16	6·36

Mean Hourly Oscillation of the Horizontal Intensity

December	0·18	0·35	0·49	0·73	0·75	0·76	1·11	1·91	3·20	4·56	5·70
January	0·34	0·11	0·42	0·36	0·50	0·61	1·12	1·72	2·92	4·30	5·81
February	0·01	0·09	0·29	0·29	0·50	0·59	0·74	1·36	2·75	4·82	6·14
March	0·23	0·39	0·37	0·45	0·57	0·59	0·61	1·43	3·13	5·07	6·56
April	0·00	0·20	0·48	0·61	0·73	0·82	1·12	2·35	4·28	6·34	8·12
May	0·16	0·21	0·21	0·19	0·31	0·49	1·21	2·32	4·03	5·49	6·52
June	0·03	0·07	0·17	0·18	0·22	0·35	1·00	2·06	3·46	4·84	5·84
July	0·12	0·22	0·32	0·21	0·49	0·72	1·33	2·37	3·83	5·12	5·94
August	0·19	0·53	0·57	0·57	0·81	0·89	1·52	2·54	4·19	5·43	6·57
September	0·09	0·39	0·71	0·89	0·94	0·85	1·23	2·44	4·37	5·95	6·80
October	0·28	0·61	0·62	0·87	0·98	0·92	0·99	1·99	3·91	5·83	7·02
November	0·11	0·30	0·41	0·73	0·66	0·69	0·87	1·81	3·36	4·88	5·95
Sums	1·74	3·77	5·06	6·08	7·46	8·28	12·85	24·30	43·43	62·63	76·97
Means	0·14	0·31	0·42	0·51	0·62	0·69	1·07	2·02	3·62	5·22	6·41
Oscillation	0·08	0·25	0·36	0·46	0·56	0·63	1·01	1·96	3·56	5·16	6·35

Mean Oscillation of the Horizontal Intensity at Singapore

1843	0·06	0·22	0·31	0·35	0·49	0·54	0·94	1·90	3·38	4·94	6·17
1844	0·12	0·21	0·40	0·38	0·58	0·62	1·07	1·97	3·51	5·00	6·09
1845	0·13	0·29	0·45	0·53	0·69	0·79	1·10	2·09	3·86	5·60	6·86
Sums	0·31	0·72	1·16	1·26	1·76	1·95	3·11	5·96	10·75	15·54	19·12
Means	0·10	0·24	0·39	0·42	0·59	0·65	1·04	1·99	3·58	5·18	6·37
Oscillation	0·09	0·23	0·38	0·41	0·58	0·64	1·03	1·98	3·57	5·17	6·36

Comparison of Horizontal Intensity in minutes of Arc between the Fixed

Bifilar Portable	.....	.....	.....	2′·19	2′·13	1′·90	2′·63	3′·22	5′·19	6′·62	8′·45
Bifilar Fixed	.....	.....	.....	0·88	0·75	0·61	1·00	1·35	4·02	6·04	8·70

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Autumn Months of 1843, 1844, 1845. In Scale Divisions. $k = \cdot 000197$.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
6·76	5·53	3·89	2·29	1·76	1·10	0·63	0·52	0·44	0·12	0·04	0·00	0·15	2·00
7·26	6·14	4·42	2·98	2·11	1·78	1·49	0·80	0·46	0·18	0·00	0·01	0·10	2·15
5·88	5·02	4·00	2·83	1·89	1·33	0·90	0·51	0·26	0·11	0·02	0·03	0·00	1·77
19·90	16·69	12·31	8·10	5·76	4·21	3·02	1·83	1·16	0·41	0·06	0·04	0·25	5·92
6·63	5·56	4·10	2·70	1·92	1·40	1·01	0·61	0·39	0·14	0·02	0·01	0·08	1·97
6·62	5·55	4·09	2·69	1·91	1·39	1·00	0·60	0·38	0·13	0·01	0·00	0·07	1·96

in the four Seasons of 1843, 1844, 1845.

6·01	5·34	4·23	3·12	2·15	1·61	1·29	0·75	0·36	0·19	0·03	0·00	0·01	1·79
7·27	6·59	5·10	3·60	2·23	1·47	1·03	0·75	0·48	0·24	0·09	0·09	0·00	2·11
6·27	5·69	4·64	3·27	1·92	1·01	0·55	0·35	0·25	0·16	0·04	0·03	0·00	1·88
6·62	5·55	4·09	2·69	1·91	1·39	1·00	0·60	0·38	0·13	0·01	0·00	0·07	1·96
26·17	23·17	18·06	12·68	8·21	5·48	3·87	2·45	1·47	0·72	0·17	0·12	0·08	7·74
6·54	5·79	4·51	3·17	2·05	1·37	0·97	0·61	0·37	0·18	0·04	0·03	0·02	1·93
6·52	5·77	4·49	3·15	2·03	1·35	0·95	0·59	0·35	0·16	0·02	0·01	0·00	1·91

for each Month of the Years 1843, 1844, 1845.

5·57	4·83	3·87	2·83	2·00	1·60	1·26	0·69	0·26	0·00	0·02	0·03	0·09	1·79
5·97	5·27	4·11	3·00	2·03	1·66	1·27	0·86	0·50	0·50	0·17	0·12	0·00	1·83
6·64	6·06	4·86	3·68	2·57	1·72	1·50	0·84	0·48	0·23	0·05	0·00	0·10	1·90
7·09	6·71	5·11	3·45	2·21	1·62	1·28	0·80	0·42	0·19	0·05	0·00	0·08	2·03
8·19	7·25	5·65	3·96	2·47	1·76	1·27	0·95	0·69	0·29	0·18	0·24	0·10	2·45
6·72	6·00	4·71	3·56	2·20	1·21	0·72	0·67	0·52	0·41	0·22	0·20	0·00	2·04
6·06	5·56	4·46	3·17	1·71	0·80	0·24	0·19	0·20	0·06	0·02	0·02	0·00	1·70
6·28	5·79	4·76	3·41	2·06	1·21	0·83	0·36	0·37	0·20	0·20	0·08	0·00	1·95
6·56	5·81	4·79	3·31	2·09	1·10	0·67	0·60	0·26	0·30	0·00	0·08	0·08	2·07
6·76	5·53	3·89	2·29	1·76	1·10	0·63	0·52	0·44	0·12	0·04	0·00	0·15	2·00
7·26	6·14	4·42	2·98	2·11	1·78	1·49	0·80	0·46	0·18	0·00	0·01	0·10	2·15
5·88	5·02	4·00	2·83	1·89	1·33	0·90	0·51	0·26	0·11	0·02	0·03	0·00	1·77
78·98	69·97	54·63	38·47	25·10	16·89	12·06	7·79	4·86	2·59	0·97	0·81	0·70	23·68
6·58	5·83	4·55	3·21	2·10	1·41	1·01	0·65	0·41	0·22	0·08	0·07	0·06	1·97
6·52	5·76	4·49	3·15	2·04	1·35	0·95	0·59	0·35	0·16	0·02	0·01	0·00	1·91

during the three Years of 1843, 1844, 1845.

6·33	5·59	4·31	2·92	1·88	1·23	0·87	0·55	0·36	0·19	0·02	0·01	0·00	1·81
6·22	5·50	4·29	3·05	1·94	1·31	0·89	0·54	0·31	0·08	0·00	0·02	0·02	1·84
7·02	6·20	4·87	3·48	2·23	1·52	1·10	0·68	0·24	0·24	0·08	0·02	0·00	2·08
19·57	17·29	13·47	9·45	6·05	4·06	2·86	1·77	0·91	0·51	0·10	0·05	0·02	5·73
6·52	5·76	4·49	3·15	2·02	1·35	0·95	0·59	0·30	0·17	0·03	0·02	0·01	1·91
6·51	5·75	4·48	3·14	2·01	1·34	0·94	0·58	0·29	0·16	0·02	0·01	0·00	1·90

Observatory Bifilar and the Portable Bifilar at Singapore, Eastern Archipelago.

8′·29	7′·11	5′·48	4′·20	3′·72	2′·45	1′·90	0′·41	0′·00	0′·37	0′·86	.....	.....	3′·54
8·88	7·69	6·18	4·15	3·07	2·18	1·45	0·32	0·00	0·02	0·18	.....	.....	3·03

Table B.

Observatory at Moulmein.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Noon.	1.
					k=·000415987 × cot 60°=·0002402. q =·0002402.					Bifilar Magnetometer.	
Sums	352·2	348·8	347·2	343·2	350·1	364·2	361·2	343·7	340·9	348·5	378·4
Means of 7 days	50·31	49·83	49·60	49·03	50·01	52·03	51·60	49·10	48·70	49·79	54·06
Temp. corrections	−0·73	−0·55	−0·05	0·00	−2·23	−8·34	−12·21	−16·61	−20·41	−23·64	−25·07
Corrected means	49·58	49·28	49·55	49·03	47·78	43·69	39·39	32·49	28·29	26·15	28·99
Oscillations & diffs.	0·00	0·30	0·03	0·55	1·80	5·89	10·19	17·09	21·29	23·43	20·59
$\frac{\delta X}{X}$	0·00	·00007	·00001	·00013	·00043	·00141	·00245	·00410	·00511	·00563	·00495
										Thermometer of Bifilar.	
Sums	536·1	534·9	531·4	531·0	547·3	589·4	616·5	647·3	673·9	696·5	706·5
Means of 7 days	76·59	76·41	75·91	75·86	78·19	84·20	88·07	92·47	96·27	99·50	100·93
Differences & corrs.	−0·73	−0·55	−0·05	0·00	−2·23	−8·34	−12·21	−16·61	−20·41	−23·64	−25·07

Observatory at Madras.—Hourly observations

					k=·000415987 × cot 60°=·0002402. q =·0002402.					Bifilar Magnetometer.	
Sums	664·2	649·9	631·4	611·8	592·4	601·7	579·6	574 5	602·4	662·9	768·5
Means of 34 days	19·54	19·11	18·57	17·99	17·42	17·70	17·05	16·90	17·72	19·50	22·60
Temp. corrections	−1·27	−0·82	−0·39	0·00	−1·10	−4·43	−8·23	−10·90	−13·32	−15·28	−16·54
Corrected means	18·27	18·29	18·18	17·99	16·32	13·27	8·82	6·00	4·40	4·22	6·06
Oscillations & diffs.	0·28	0·26	0·37	0·56	2·23	5·28	9·73	12·55	14·15	14·33	12·49
$\frac{\delta X}{X}$	·00007	·00006	·00009	·00013	·00053	·00127	·00234	·00301	·00340	·00344	·00300
										Thermometer of Bifilar.	
Sums	2685·9	2670·8	2656·2	2642·7	2680·3	2793·5	2922·6	3013·4	3095·7	3162·5	3205·2
Means of 34 days	79·00	78·55	78·12	77·73	78·83	82·16	'85·96	88·63	91·05	93·01	94·27
Differences & corrs.	−1·27	−0·82	−0·39	0·00	−1·10	−4·43	−8·23	−10·90	−13·32	−15·28	−16·54

Table B.

made during the Month of April, 1849.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\partial X}{X}$
X=8·1186. Zero from the 14th to the 21st. Scale Divisions 51·72. Thermometer 80°·0.													
	386·7	390·0	394·0	397·5	375·1	350·4	352·3	354·5	6878·9	362·0			
	55·24	55·71	56·29	56·79	53·59	50·06	50·33	50·64	982·71	51·72	−8·1	43·6	+ ·001946
	−26·50	−24·68	−22·47	−19·58	−12·31	−7·15	−5·30	−4·12					
	28·74	31·03	33·82	37·21	41·28	42·91	45·03	46·52					
	20·84	18·55	15·76	12·37	8·30	6·67	4·55	3·06					
	·00501	·00446	·00379	·00297	·00199	·00160	·00109	·00073					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$													
	716·5	703·8	688·3	668·1	617·2	581·1	568·1	559·8	11713·7	616·9			
	102·36	100·54	98·33	95·44	88·17	83·01	81·16	79·98	1673·39	88·07	−8·1		
	−26·50	−24·68	−22·47	−19·58	−12·31	−7·15	−5·30	−4·12					

made during the Month of August and September, 1849.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\partial X}{X}$
X=8·0784. Zero from the 14th to the 21st. Scale Divisions 21·04. Thermometer 80°.													
	862·2	878·7	886·1	842·4	817·2	795·9	792·1	776·7	13590·6	715·2			
	25·36	25·84	26·06	24·78	24·04	23·41	23·30	22·85	399·74	21·04	−5·6	15·44	+ ·001345
	−16·19	−14·70	−13·15	−10·74	−7·91	−5·83	−4·91	−4·30					
	9·17	11·14	12·91	14·04	16·13	17·58	18·39	18·55					
	9·38	7·41	5·64	4·51	2·42	0·97	0·16	0·00					
	·00225	·00178	·00135	·00108	·00058	·00023	·00004	0·00					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$													
	3193·4	3142·5	3089·9	3008·0	2911·8	2841·2	2809·8	2789·0	55314·4	2911·0			
	93·92	92·43	90·88	88·47	85·64	83·56	82·64	82·03	1626·88	85·63	−5·6		
	−16·19	−14·70	−13·15	−10·74	−7·91	−5·83	−4·91	−4·30					

TABLE B.

Observatory at Car Nicobar.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \cdot 0002402.$			$= \cdot 0002402.$		Bifilar Magnetometer.	
Sums	458·8	457·9	456·1	454·1	460·3	463·8	462·0	456·5	458·6	457·9	455·4
Means of 5 days	91·76	91·58	91·22	90·82	92·06	92·76	92·40	91·30	91·72	91·58	91·08
Temp. corrections	0·00	−0·18	−0·40	−0·68	−1·08	−4·50	−8·04	−11·50	−13·70	−14·30	−15·02
Corrected means	91·76	91·40	90·82	90·14	90·98	88·26	84·36	79·80	78·02	77·28	76·06
Oscillations & diffs.	+2·50	2·86	3·44	4·12	3·28	6·00	9·90	14·46	16·24	16·98	18·20
$\frac{\partial X}{X}$	·00060	·00069	·00083	·00099	·00079	·00144	·00238	·00347	·00390	·00408	·00437
										Thermometer of Bifilar.	
Sums	365·3	366·2	367·3	368·7	370·7	387·8	405·5	422·8	433·8	436·8	440·4
Means of 5 days	73·06	73·24	73·46	73·74	74·14	77·56	81·10	84·56	86·76	87·36	88·08
Differences & corrs.	0·00	−0·18	−0·40	−0·68	−1·08	−4·50	−8·04	−11·50	−13·70	−14·30	−15·02

Observatory at Samboanga.—Hourly observations

					$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \cdot 0002402.$			$= \cdot 0002402.$		Bifilar Magnetometer.	
Sums	787·0	786·0	785·7	781·0	790·9	813·5	817·4	808·1	792·1	792·3	800·4
Means of 6 days	131·17	131·00	130·95	130·17	131·82	135·58	136·23	134·68	132·02	132·05	133·40
Temp. corrections	−0·34	−0·15	−0·20	0·00	−3·52	−9·22	−11·95	−13·42	−12·44	−13·79	−14·99
Corrected means	130·83	130·85	130·75	130·17	128·30	126·36	124·28	121·26	119·58	118·26	118·41
Oscillations & diffs.	0·02	0·00	0·10	0·68	2·55	4·49	6·57	9·59	11·27	12·59	12·44
$\frac{\partial X}{X}$	·00001	0·00	·00002	·00016	·00061	·00108	·00158	·00230	·00271	·00302	·00299
										Thermometer of Bifilar.	
Sums	446·2	445·1	445·4	444·2	465·3	499·5	515·9	524·7	518·8	526·9	534·1
Means of 6 days	74·37	74·18	74·23	74·03	77·55	83·25	85·98	87·45	86·47	87·82	89·02
Differences & corrs.	−0·34	−0·15	−0·20	0·00	−3·52	−9·22	−11·95	−13·42	−12·44	−13·79	−14·99

TABLE B.

during the Month of February, 1849.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
X=8·1555. Zero from the 6th to the 10th. Scale Divisions 94·52. Thermometer 80°.													
	470·6	494·6	500·1	502·9	496·7	493·6	490·7	489·0	8979·6	472·6			
	94·12	98·92	100·02	100·58	99·34	98·72	98·14	97·80	1795·92	94·52	−0·6	93·92	+·000144
	−13·84	−12·98	−12·82	−11·64	−8·44	−5·94	−4·68	−3·54					
	80·28	85·94	87·20	88·94	90·90	92·78	93·46	94·26					
	13·98	8·32	7·06	5·32	3·36	1·48	0·80	0·00					
	·00336	·00200	·00170	·00128	·00081	·00036	·00019	0·00					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	434·5	430·2	429·4	423·5	407·5	395·0	388·7	383·0	7657·1	403·1			
	86·90	86·04	85·88	84·70	81·50	79·00	77·74	76·60	1531·42	80·60	−0·6		
	−13·84	−12·98	−12·82	−11·64	−8·44	−5·94	−4·68	−3·54					

made during the Month of May, 1848.

X=8·162. Zero from the 25th to the 31st. Scale Divisions 134·62. Thermometer 80°.													
	819·9	836·6	843·4	837·1	822·5	818·7	812·1	801·5	15346·2	807·7			
	136·65	139·43	140·57	139·52	137·08	136·45	135·35	133·58	2557·70	134·62	−2·48	132·14	+·000596
	−15·37	−14·59	−13·25	−10·94	−8·65	−7·05	−5·92	−4·70					
	121·28	124·84	127·32	128·58	128·43	129·40	129·43	128·88					
	9·57	6·01	3·53	2·27	2·42	1·45	1·42	1·97					
	·00230	·00144	·00085	·00054	·00058	·00035	·00034	·00047					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	536·4	531·7	523·7	509·8	496·1	486·5	479·7	472·4	9402·4	494·9			
	89·40	88·62	87·28	84·97	82·68	81·08	79·95	78·73	1567·06	82·48	−2·48		
	−15·37	−14·59	−13·25	−10·94	−8·65	−7·05	−5·92	−4·70					

TABLE B.

Observatory at Penang.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					k=·000415987 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer.
Sums	423·3	421·3	419·1	415·8	414·4	401·2	399·2	401·9	401·0	423·5	433·7
Means of 5 days	84·66	84·26	83·82	83·16	82·88	80·24	79·84	80·38	80·20	84·70	86·74
Temp. corrections	−1·22	−0·96	0·00	0·00	−0·96	−2·82	−6·64	−10·30	−12·94	−13·76	−12·62
Corrected means	83·44	83·30	83·82	83·16	81·92	77·42	73·20	70·08	67·26	70·94	74·12
Oscillations & diffs.	0·38	0·52	0·00	0·66	1·90	6·40	10·62	13·74	16·56	12·88	9·70
$\frac{\delta X}{X}$	·00009	·00012	0·000	·00016	·00046	·00154	·00255	·00330	·00398	·00309	·00233
											Thermometer of Bifilar.
Sums	381·1	379·8	375·0	375·0	379·8	389·1	408·2	426·5	439·7	443·8	438·1
Means of 5 days	76·22	75·96	75·00	75·00	75·96	77·82	81·64	85·30	87·94	88·76	87·62
Differences & corrs.	−1·22	−0·96	0·00	0·00	−0·96	−2·82	−6·64	−10·30	−12·94	−13·76	−12·62

Observatory at Pulo Dinding.—Hourly observations

					k=·000415987 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer.
Sums	168·4	166·4	165·5	162·9	159·9	161·6	166·3	172·0	177·8	182·3	191·5
Means of 2 days	84·20	83·20	82·75	81·45	79·95	80·80	83·15	86·00	88·90	91·15	95·75
Temp. corrections	−1·90	−1·10	−0·85	0·00	−0·20	−3·85	−9·30	−15·05	−19·15	−20·60	−21·20
Corrected means	82·30	82·10	81·90	81·45	79·75	76·95	73·85	70·95	69·75	70·55	74·55
Oscillations & diffs.	0·00	0·20	0·40	0·85	2·55	5·35	8·45	11·35	12·35	11·75	7·75
$\frac{\delta X}{X}$	0·00	·00005	·00009	·00020	·00061	·00128	·00203	·00273	·00301	·00282	·00186
											Thermometer of Bifilar.
Sums	150·8	149·2	148·7	147·0	147·4	154·7	165·6	177·1	185·3	188·2	189·4
Means of 2 days	75·40	74·60	74·35	73·50	73·70	77·35	82·80	88·55	92·65	94·10	94·70
Differences & corrs.	−1·90	−1·10	−0·85	0·00	−0·20	−3·85	−9·30	−15·05	−19·15	−20·60	−21·20

Table B.

made during the Month of January, 1849.

2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
X=8·159. Zero from the 22nd to the 26th. Scale Divisions 84·85. Thermometer 80°.												
448·1	461·1	449·5	442·6	435·3	427·9	423·1	418·5	8060·5	424·2			
89·62	92·22	89·90	88·52	87·06	85·58	84·62	83·70	1612·10	84·85	−1·42	83·43	+ ·000341
−11·02	−11·64	−9·92	−8·34	−6·68	−4·86	−3·94	−3·36					
78·60	80·58	79·98	80·18	80·38	80·72	80·68	80·34					
5·22	3·24	3·84	3·64	3·44	3·10	3·14	3·48					
·00125	·00078	·00092	·00087	·00081	·00074	·00075	·00084					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$												
430·1	433·2	424·6	416·7	408·4	399·3	394·7	391·8	7734·9	407·2			
86·02	86·64	84·92	83·34	81·68	79·86	78·94	78·36	1546·98	81·42	−1·42		
−11·02	−11·64	−9·92	−8·34	−6·68	−4·86	−3·94	−3·36					

made during the Month of January, 1849.

X=8·117. Zero from the 12th to the 13th. Scale Divisions 87·30. Thermometer 80°.												
193·5	192·4	187·2	181·2	174·3	172·3	172·4	169·5	3317·4	174·6			
96·75	96·20	93·60	90·60	87·15	86·15	86·20	84·75	1658·70	87·30	−2·55	84·75	+ ·000613
−19·30	−16·95	−12·65	−9·75	−7·00	−5·05	−4·15	−3·95					
77·45	79·25	80·95	80·85	80·15	81·10	82·05	80·80					
4·85	3·05	1·35	1·45	2·15	1·20	0·25	1·50					
·00116	·00073	·00032	·00035	·00052	·00029	·00006	·00036					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$												
185·6	180·9	172·3	166·5	161·0	157·1	155·3	154·9	3137·0	165·1			
92·80	90·45	86·15	83·25	80·50	78·55	77·65	77·45	1568·50	82·25	−2·55		
−19·30	−16·95	−12·65	−9·75	−7·00	−5·05	−4·15	−3·95					

Table B.

Observatory at Keemah.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \frac{\cdot 0002402.}{\cdot 0002402.}$						Bifilar Magnetometer.
Sums	587·5	583·7	581·3	573·4	578·4	556·5	629·8	636·8	588·6	602·8	644·8
Means of 10 days	58·75	58·37	58·13	57·34	57·84	61·83	62·98	63·68	65·40	66·98	64·48
Temp. corrections	−0·70	−0·44	−0·29	0·00	−1·91	−8·13	−11·62	−14·27	−17·00	−18·72	−15·17
Corrected means	58·05	57·93	57·84	57·34	55·93	53·70	51·36	49·41	48·40	48·26	49·31
Oscillations & diffs.	0·00	0·12	0·21	0·71	2·12	4·35	6·69	8·64	9·65	9·79	8·74
$\frac{\delta X}{X}$	0·00	·00003	·00005	·00017	·00051	·00104	·00161	·00208	·00232	·00235	·00210
											Thermometer of Bifilar.
Sums	734·6	732·0	730·5	727·6	746·7	728·0	843·8	870·3	807·8	823·3	879·3
Means of 10 days	73·46	73·20	73·05	72·76	74·67	80·89	84·38	87·03	89·76	91·48	87·93
Differences & corrs.	−0·70	−0·44	−0·29	0·00	−1·91	−8·13	−11·62	−14·27	−17·00	−18·72	−15·17

Observatory at Sarawak.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \frac{\cdot 0002402.}{\cdot 0002402.}$							Bifilar Magnetometer.
Sums	2177·1	2166·3	2157·2	2145·2	2139·6	2130·4	2111·7	2085·4	2079·0	2093·8	2133·6	2179·1	2230·5
Means of 26 days	83·73	83·32	82·97	82·51	82·29	81·94	81·22	80·21	79·96	80·53	82·06	83·81	85·79
Temp. corrections	−1·50	−1·28	−1·03	−0·77	−0·47	−0·25	0·00	−0·02	−1·08	−3·25	−5·62	−7·58	−9·07
Corrected means	82·23	82·04	81·94	81·74	81·82	81·69	81·22	80·19	78·88	77·28	76·44	76·23	76·72
Oscillations & diffs.	0·49	0·68	0·78	0·98	0·90	1·03	1·50	2·53	3·84	5·44	6·28	6·49	6·00
$\frac{\delta X}{X}$	·00012	·00016	·00019	·00023	·00022	·00025	·00036	·00061	·00092	·00131	·00151	·00156	·00144
													Thermometer of Bifilar.
Sums	2012·5	2006·7	2000·2	1993·4	1985·7	1979·9	1973·4	1973·8	2001·6	2057·9	2119·5	2170·4	2209·3
Means of 26 days	77·40	77·18	76·93	76·67	76·37	76·15	75·90	75·92	76·98	79·15	81·52	83·48	84·97
Differences & corrs.	−1·50	−1·28	−1·03	−0·77	−0·47	−0·25	0·00	−0·02	−1·08	−3·25	−5·62	−7·58	−9·07

Table B.

made during the Months of June and July, 1848.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
X=8·253. Zero from the 21st to the 1st. Scale Divisions 61·86. Thermometer 80°.													
	629·2	635·7	646·9	642·7	630·4	615·7	606·6	596·1	11566·9	617·9			
	62·92	63·57	64·69	64·27	63·04	61·57	60·66	59·61	1176·11	61·86	−0·74	61·12	+·000178
	−12·70	−11·31	−10·60	−8·94	−7·04	−5·82	−4·87	−4·05					
	50·22	52·26	54·09	55·33	56·00	55·75	55·79	55·56					
	7·83	5·79	3·96	2·72	2·05	2·30	2·26	2·49					
	·00188	·00139	·00095	·00065	·00049	·00055	·00054	·00060					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$													
	854·6	840·7	833·6	817·0	798·0	785·8	776·3	768·1	15098·0	807·2			
	85·46	84·07	83·36	81·70	79·80	78·58	77·63	76·81	1536·02	80·74	−0·74		
	−12·70	−11·31	−10·60	−8·94	−7·04	−5·82	−4·87	−4·05					

made during the Month of June, 1846.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Temp. Corrs.	Corr. Means.	$\frac{\delta X}{X}$
X=8·186. Zero from the 1st to the 30th. Scale Divisions 84·58. Thermometer 80°.																
	2275·2	2311·7	2328·6	2331·4	2326·8	2289·7	2249·9	2231·3	2215·4	2200·9	2189·0	52778·8	2199·3			
	87·51	88·91	89·56	89·67	89·49	88·07	86·53	85·82	85·21	84·65	84·19	2029·95	84·58	+0·15	84·73	−·000036
	−9·74	−9·85	−9·12	−8·16	−7·09	−5·37	−3·96	−3·10	−2·52	−2·16	−1·79					
	77·77	79·06	80·44	81·51	82·40	82·70	82·57	82·72	82·69	82·49	82·40					
	4·95	3·66	2·28	1·21	0·32	0·02	0·15	0·00	0·03	0·23	0·32					
	·00119	·00088	·00055	·00029	·00008	·00001	·00004	0·00	·00001	·00005	·00008					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$																
	2226·6	2229·5	2210·5	2185·5	2157·8	2113·0	2076·4	2053·9	2038·8	2029·6	2020·0	49825·9	2075·9			
	85·64	85·75	85·02	84·06	82·99	81·27	79·86	79·00	78·42	78·06	77·69	1916·38	79·85	+0·15		
	−9·74	−9·85	−9·12	−8·16	−7·09	−5·37	−3·96	−3·10	−2·52	−2·16	−1·79					

Table B.

Observatory at Sarawak.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$\frac{q}{k}$=·000415987 × cot 60°=·0002402. =·0002402.						Bifilar Magnetometer.	
Sums	2351·3	2333·3	2318·5	2310·1	2303·6	2293·2	2274·6	2247·7	2223·9	2237·4	2260·5	2302·4	2360·5
Means of 27 days	87·09	86·42	85·87	85·56	85·32	84·93	84·24	83·25	82·37	82·87	83·72	85·27	87·43
Temp. corrections	−1·77	−1·43	−1·11	−0·78	−0·61	−0·53	−0·20	0·00	−0·87	−2·84	−4·78	−6·52	−8·15
Corrected means	85·32	84·99	84·76	84·78	84·71	84·40	84·04	83·25	81·50	80·03	78·94	78·75	79·28
Oscillations & diffs.	0·51	0·84	1·07	1·05	1·12	1·43	1·79	2·58	4·33	5·80	6·89	7·08	6·55
$\frac{\delta X}{X}$	·00012	·00020	·00026	·00025	·00027	·00034	·00043	·00062	·00104	·00139	·00165	·00170	·00157
												Thermometer of Bifilar.	
Sums	2082·4	2073·2	2064·8	2055·8	2051·3	2049·1	2040·2	2034·6	2058·2	2111·3	2163·8	2210·7	2254·8
Means of 27 days	77·13	76·79	76·47	76·14	75·97	75·89	75·56	75·36	76·23	78·20	80·14	81·88	83·51
Differences & corrs.	−1·77	−1·43	−1·11	−0·78	−0·61	−0·53	−0·20	0·00	−0·87	−2·84	−4·78	−6·52	−8·15

Observatory at Sarawak.—Hourly observations

						$\frac{k}{q}$=·000415987 × cot 60°=·0002402. =·0002402.						Bifilar Magnetometer.	
Sums	1709·9	1705·6	1694·5	1686·8	1676·4	1670·7	1659·8	1645·8	1643·5	1651·3	1681·0	1711·4	1751·0
Means of 19 days	89·99	89·77	89·18	88·78	88·23	87·93	87·36	86·62	86·50	86·91	88·47	90·07	92·16
Temp. corrections	−1·64	−1·38	−1·05	−0·76	−0·58	−0·38	−0·10	0·00	−0·95	−3·22	−5·47	−7·25	−9·05
Corrected means	88·35	88·39	88·13	88·02	87·65	87·55	87·26	86·62	85·55	83·69	83·00	82·82	83·11
Oscillations & diffs.	0·55	0·51	0·77	0·88	1·25	1·35	1·64	2·28	3·35	5·21	5·90	6·08	5·79
$\frac{\delta X}{X}$	·00013	·00012	·00018	·00021	·00030	·00032	·00039	·00055	·00080	·00125	·00142	·00146	·00139
												Thermometer of Bifilar.	
Sums	1455·8	1450·9	1444·6	1439·0	1435·7	1431·8	1426·6	1424·6	1442·6	1485·8	1528·5	1562·4	1596·6
Means of 19 days	76·62	76·36	76·03	75·74	75·56	75·36	75·08	74·98	75·93	78·20	80·45	82·23	84·03
Differences & corrs.	−1·64	−1·38	−1·05	−0·76	−0·58	−0·38	−0·10	0·00	−0·95	−3·22	−5·47	−7·25	−9·05

TABLE B.

made during the Month of July, 1846.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Temp. Corrs.	Corr. Means.	$\frac{\delta X}{X}$
Zero from the 1st to the 31st. Scale Divisions 87·26. Thermometer 80°.															
2417·5	2454·1	2483·2	2496·5	2479·1	2474·3	2419·6	2398·3	2379·4	2368·6	2355·7	56543·3	2355·7			
89·54	90·89	91·97	92·46	91·82	91·64	89·61	88·83	88·13	87·73	87·25	2094·21	87·26	+0·82	88·08	−·000197
−8·87	−9·23	−8·63	−8·14	−7·20	−5·81	−3·98	−3·20	−2·74	−2·35	−1·98					
80·67	81·66	83·34	84·32	84·62	85·83	85·63	85·63	85·39	85·38	85·27					
5·06	4·17	2·49	1·51	1·21	0·00	0·20	0·20	0·44	0·45	0·56					
·00124	·00100	·00060	·00036	·00029	0·00	·00005	·00005	·00011	·00011	·00013					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$															
2274·2	2284·0	2267·7	2254·4	2229·1	2191·6	2142·3	2121·2	2108·8	2098·1	2088·1	51309·7	2137·9			
84·23	84·59	83·99	83·50	82·56	81·17	79·34	78·56	78·10	77·71	77·34	1900·36	79·18	+0·82		
−8·87	−9·23	−8·63	−8·14	−7·20	−5·81	−3·98	−3·20	−2·74	−2·35	−1·98					

made during the Month of August, 1846.

Zero from the 1st to the 22nd. Scale Divisions 90·83. Thermometer 80°.															
1793·5	1816·0	1831·9	1818·8	1805·8	1789·9	1655·0	1645·5	1645·2	1641·5	1632·0	40963·7	1725·3			
94·39	95·63	76·42	95·73	95·04	94·21	91·94	91·42	91·40	91·19	90·67	2180·01	90·83	+0·91	91·74	−·000219
−10·41	−10·71	−10·21	−8·41	−7·20	−5·85	−3·75	−2·99	−2·53	−2·29	−1·99					
83·98	84·92	86·21	87·32	87·84	88·36	88·19	88·43	88·87	88·90	88·68					
4·92	3·98	1·69	1·58	1·06	0·54	0·71	0·47	0·03	0·00	0·22					
·00118	·00095	·00041	·00038	·00040	·00013	·00017	·00011	·00001	0·00	·00005					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$															
1622·4	1628·1	1618·6	1584·5	1561·5	1535·8	1417·1	1403·5	1395·2	1390·8	1385·4	35667·8	1503·1			
85·39	85·69	85·19	83·39	82·18	80·83	78·73	77·97	77·51	77·27	76·97	1897·69	79·09	+0·91		
−10·41	−10·71	−10·21	−8·41	−7·20	−5·85	−3·75	−2·99	−2·53	−2·29	−1·99					

TABLE B.

Observatory at Pulo Peesang.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					k=·000415987 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer.
Sums	.....	.....	270·0	340·9	340·4	344·5	351·5	369·6	386·8	389·8	398·1
Means of 5 days	.....	.....	67·50	68·18	68·08	68·90	70·30	73·92	77·36	77·96	79·62
Temp. corrections	.....	.....	−2·35	0·00	−1·14	−3·52	−7·94	−12·44	−15·04	−14·78	−14·60
Corrected means	.....	.....	65·15	68·18	66·94	65·38	62·36	61·48	62·32	63·18	65·02
Oscillations & diffs.	.....	.....	3·23	0·20	1·44	3·00	6·02	6·90	6·06	5·20	3·36
$\frac{\delta X}{X}$	.....	.....	·00078	·00005	·00035	·00072	·00145	·00166	·00146	·00125	·00081
											Thermometer of Bifilar.
Sums	.....	.....	310·9	376·9	382·6	394·5	416·6	439·1	452·1	450·8	449·9
Means of 5 days	.....	.....	77·73	75·38	76·52	78·90	83·32	87·82	90·42	90·16	89·98
Differences & corrs.	.....	.....	−2·35	0·00	−1·14	−3·52	−7·94	−12·44	−15·04	−14·78	−14·60

Observatory at Singapore.—Hourly observations

					k=·000415987 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer No. I.
Sums	1881·6	1880·9	1879·6	1872·1	1899·2	1900·5	1928·7	1942·2	1967·2	1992·3	2002·5
Means of 16 days	117·60	117·56	117·48	117·01	118·70	118·78	120·54	121·39	122·95	124·52	125·16
Temp. corrections	−0·59	−0·42	−0·09	0·00	−1·64	−3·97	−6·37	−8·45	−9·62	−9·99	−9·50
Corrected means	117·01	117·14	117·39	117·01	117·06	114·81	114·17	112·94	113·33	114·53	115·66
Oscillations & diffs.	2·41	2·28	2·03	2·41	2·36	4·61	5·25	6·48	6·09	4·89	3·76
$\frac{\delta X}{X}$	·00058	·00055	·00049	·00058	·00057	·00111	·00126	·00156	·00146	·00117	·00090
											Thermometer of Bifilar No. I.
Sums	1207·6	1204·9	1199·6	1198·2	1224·4	1261·7	1300·2	1333·5	1352·1	1358·1	1350·2
Means of 16 days	75·48	75·31	74·98	74·89	76·53	78·86	81·26	83·34	84·51	84·88	84·39
Differences & corrs.	−0·59	−0·42	−0·09	0·00	−1·64	−3·97	−6·37	−8·45	−9·62	−9·99	−9·50

Table B.

Month of January, 1846.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
X=8·092. Zero from the 18th to the 22nd. Scale Divisions 72·18. Thermometer 80°.													
	388·8	373·2	366·2	289·3	345·9	342·5	279·6	211·8	5918·6	360·2			
	77·76	74·64	73·24	72·33	69·18	68·50	69·90	70·60	1292·82	72·18	−2·17	70·01	+·000521
	−11·42	−8·12	−7·08	−5·07	−2·98	−2·50	−3·00	−2·22					
	66·34	66·52	66·16	67·26	66·20	66·00	66·90	68·38					
	2·04	1·86	2·22	1·12	2·18	2·38	1·48	0·00					
	·00049	·00045	·00053	·00027	·00052	·00057	·00035	0·000					
$\frac{q}{k}=\frac{·0002402}{·0002402}=1.$													
	434·0	417·5	412·3	321·8	391·8	389·4	313·5	232·8	6738·3	410·8			
	86·80	83·50	82·46	80·45	78·36	77·88	78·38	77·60	1471·56	82·17	−2·17		
	−11·42	−8·12	−7·08	−5·07	−2·98	−2·50	−3·00	−2·22					

Month of November, 1848.

	2014·3	2004·5	2001·6	1999·9	1986·7	1975·9	1956·4	1946·0	37032·1	1949·0			
X=8·115. Zero from the 13th to the 30th. Scale Divisions 121·82. Thermometer 80°.													
	125·89	125·28	125·10	124·99	124·17	123·49	122·28	121·63	2314·52	121·82	−0·07	121·75	+·000017
	−9·08	−8·39	−7·84	−7·14	−5·06	−4·07	−3·33	−2·99					
	116·81	116·89	117·26	117·85	119·11	119·42	118·95	118·64					
	2·81	2·53	2·16	1·57	0·31	0·00	0·47	0·78					
	·00063	·00061	·00052	·00038	·00007	0·00	·00011	·00019					
$\frac{q}{k}=\frac{·0002402}{·0002402}=1.$													
	1343·5	1332·4	1323·7	1312·5	1279·2	1263·3	1251·5	1246·0	24342·6	1281·1			
	83·97	83·28	82·73	82·03	79·95	78·96	78·22	77·88	1521·45	80·07	−0·07		
	−9·08	−8·39	−7·84	−7·14	−5·06	−4·07	−3·33	−2·99					

TABLE B.

Observatory at Singapore.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
				$\frac{k}{q}$ = ·0003136 × cot 58° 10′ 30″ = ·0001969. = ·000214.							Bifilar Magnetometer No. II.
Sums	513·2	515·3	517·7	509·5	503·1	454·7	435·6	402·3	411·1	442·4	465·5
Means of 16 days	32·08	32·21	32·36	31·84	31·44	28·42	27·23	25·14	25·70	27·65	29·09
Temp. corrections	−0·63	−0·40	−0·37	−0·25	0·00	−0·07	−0·38	−0·93	−1·43	−1·70	−2·01
Corrected Means	31·45	31·81	31·99	31·59	31·44	28·37	26·85	24·21	24·27	25·95	27·08
Oscillations & diffs.	1·95	1·59	1·41	1·81	1·96	5·03	6·55	9·19	9·13	7·45	6·32
$\frac{\partial X}{X}$	·00038	·00031	·00028	·00036	·00039	·00099	·00129	·00181	·00180	·00147	·00124
											Thermometer of Bifilar No. II.
Sums	1276·6	1273·2	1272·6	1271·0	1267·3	1268·3	1273·0	1281·1	1288·4	1292·4	1297·0
Means of 16 days	79·79	79·58	79·54	79·44	79·21	79·27	79·56	80·07	80·53	80·78	81·06
Differences	−0·58	−0·37	−0·34	−0·23	0·00	−0·06	−0·35	−0·86	−1·32	−1·57	−1·85
Corrections	−0·63	−0·40	−0·37	−0·25	0·00	−0·07	−0·38	−0·93	−1·43	−1·70	−2·01

Observatory at Singapore.—Hourly observations

				$\frac{k}{q}$ = ·000415987 × cot 60° = ·0002402. = ·0002402.							Bifilar Magnetometer No. I.
Sums	1696·8	1690·6	1685·1	1674·8	1685·2	1732·5	1755·5	1755·4	1769·1	1782·7	1795·6
Means of 14 days	121·20	120·76	120·36	119·63	120·37	123·75	125·39	125·39	126·36	127·34	128·26
Temp. corrections	−0·95	−0·57	−0·10	−0·00	−1·61	−5·50	−8·50	−9·84	−10·97	−11·50	−11·26
Corrected Means	120·25	120·19	120·26	119·63	118·76	118·25	116·89	115·55	115·39	115·84	117·00
Oscillations & diffs.	0·65	0·71	0·64	1·27	2·14	2·65	4·01	5·35	5·51	5·06	3·90
$\frac{\partial X}{X}$	·00016	·00017	·00015	·00030	·00051	·00064	·00096	·00128	·00132	·00122	·00094
											Thermometer of Bifilar No. I.
Sums	1055·4	1050·2	1043·5	1042·2	1064·7	1119·1	1161·1	1179·9	1195·8	1203·2	1199·8
Means of 14 days	75·39	75·01	74·54	74·44	76·05	79·94	82·94	84·28	85·41	85·94	85·70
Correction & differs.	−0·95	−0·57	−0·10	0·00	−1·61	−5·50	−8·50	−9·84	−10·97	−11·50	−11·26

TABLE B.

made during the Month of November, 1848.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 13th to the 30th. Scale Divisions 30·91. Thermometer 80°.													
	501·8	513·3	518·4	529·4	549·1	557·6	547·7	535·6	9423·3	496·2			
	31·36	32·08	32·40	33·09	34·32	34·85	34·23	33·48	586·76	30·91	−0·24	30·67	+·000047
	−2·13	−2·03	−1·88	−1·77	−1·52	−1·45	−1·16	−0·74					
	29·23	30·05	30·52	31·32	32·80	33·40	33·07	32·74					
	4·17	3·35	2·88	2·08	0·60	0·00	0·37	0·66					
	·00082	·00066	·00057	·00041	·00012	0·00	·00007	·00013					
$\frac{q}{k}=\frac{\cdot000214}{\cdot000197}=1\cdot086.$													
	1298·7	1297·2	1295·0	1293·4	1289·8	1288·7	1284·5	1278·3	24386·5	1283·4			
	81·17	81·08	80·94	80·84	80·61	80·54	80·28	79·89	1524·18	80·22	−0·22		
	−1·96	−1·87	−1·73	−1·63	−1·40	−1·33	−1·07	−0·68					
	−2·13	−2·03	−1·88	−1·77	−1·52	−1·45	−1·16	−0·74					

made during the Month of December, 1848.

	1.	2.	3.	4.	5.	6.	7.	8.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 1st to the 16th. Scale Divisions 124·90. Thermometer 80°.													
	1792·0	1807·3	1809·0	1788·1	1767·0	1755·1	1746·1	1735·4	33223·3	1748·8			
	128·00	129·09	129·21	127·72	126·21	125·36	124·72	123·96	2373·08	124·90	−0·61	124·29	+·000146
	−10·37	−10·87	−9·58	−7·92	−5·78	−4·46	−3·89	−3·49					
	117·63	118·22	119·63	119·80	120·63	120·90	120·83	120·47					
	3·27	2·68	1·27	1·10	0·27	0·00	0·07	0·43					
	·00078	·00064	·00030	·00026	·00006	0·00	·00002	·00010					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	1187·4	1194·3	1176·3	1153·1	1123·1	1104·6	1096·6	1091·0	21441·3	1128·4			
	84·81	85·31	84·02	82·36	80·22	78·90	78·33	77·93	1531·52	80·61	−0·61		
	−10·37	−10·87	−9·58	−7·92	−5·78	−4·46	−3·89	−3·49					

TABLE B.

Observatory at Singapore.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
				$k = \frac{\cdot0003136 \times \cot 58° 10' 30''}{q} = \frac{\cdot0001969}{\cdot000214}$.				Bifilar Magnetometer No. II.			
Sums	387·2	384·8	384·5	376·8	340·5	342·0	317·7	293·5	293·8	306·7	333·1
Means of 14 days	27·66	27·49	27·46	26·91	26·19	24·43	22·69	20·96	20·99	21·91	23·79
Temp. corrections	−0·61	−0·58	−0·46	−0·24	0·00	−0·14	−0·62	−1·19	−1·59	−2·00	−2·21
Corrected means	27·05	26·91	27·00	26·67	26·19	24·29	22·07	19·77	19·40	19·91	21·58
Oscillations & diffs.	0·00	0·14	0·05	0·38	0·86	2·76	4·98	7·28	7·65	7·14	5·47
$\frac{\delta X}{X}$	0·00	·00003	·00001	·00007	·00017	·00054	·00098	·00143	·00151	·00141	·00108
										Thermometer of Bifilar No. II.	
Sums	1110·0	1109·7	1108·2	1105·3	1102·2	1104·1	1110·2	1117·5	1122·6	1128·1	1130·7
Means of 14 days	79·29	79·26	79·16	78·95	78·73	78·86	79·30	79·82	80·19	80·58	80·76
Differences	−0·56	−0·53	−0·43	−0·22	0·00	−0·13	−0·57	−1·09	−1·46	−1·85	−2·03
Corrections	−0·61	−0·58	−0·46	−0·24	0·00	−0·14	−0·62	−1·19	−1·59	−2·00	−2·21

Observatory at Carimon Island.—Hourly observations

				$k = \frac{\cdot000415987 \times \cot 60°}{q} = \frac{\cdot0002402}{\cdot0002402}$.				Bifilar Magnetometer.			
Sums	.....	.....	442·4	525·5	533·9	541·0	548·1	557·5	577·0	597·4	602·3
Means of 6 days	.....	.....	88·48	87·58	88·98	90·17	91·35	92·92	96·17	99·57	100·38
Temp. corrections	.....	.....	−0·29	0·00	−2·80	−5·77	−9·02	−10·92	−13·88	−13·88	−13·95
Corrected means	.....	.....	88·19	87·58	86·18	84·40	82·33	82·00	82·29	85·69	86·43
Oscillations & diffs.	.....	.....	0·46	1·07	2·47	4·25	6·32	6·65	6·36	2·96	2·22
$\frac{\delta X}{X}$	.....	.....	·00011	·00026	·00059	·00102	·00152	·00160	·00153	·00071	·00053
										Thermometer of Bifilar.	
Sums	.....	.....	384·2	459·3	476·1	493·9	513·4	524·8	542·6	542·6	543·0
Means of 6 days	.....	.....	76·84	76·55	79·35	82·32	85·57	87·47	90·43	90·43	90·50
Differences & corrs.	.....	.....	0·29	0·00	−2·80	−5·77	−9·02	−10·92	−13·88	−13·88	−13·95

TABLE B.

made during the Month of December, 1848.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 1st to the 16th. Scale Divisions 25·9. Thermometer 80°.													
	355·0	372·1	388·6	393·6	397·5	401·5	397·1	393·2	6859·2	362·3			
	25·36	26·58	27·76	28·11	28·39	28·68	28·36	28·09	491·81	25·88	+0·13	26·01	−·000026
	−2·17	−2·20	−2·20	−1·99	−1·66	−1·93	−1·31	−1·04					
	23·19	24·38	25·56	26·12	26·73	2 ·75	27·05	27·05					
	3·86	2·67	1·49	0·93	0·32	0·32	0·00	0·00					
	·00076	·00052	·00029	·00018	·00006	·00006	0·00	0·00					
$\frac{q}{k}=\frac{\cdot000214}{\cdot000197}=1\cdot1.$													
	1130·2	1130·7	1130·7	1127·9	1123·7	1121·5	1119·1	1115·7	21248·1	1118·4			
	80·73	80·76	80·76	80·56	80·26	80·11	79·94	79·69	1517·71	79·88	+0·12		
	−2·00	−2·03	−2·03	−1·83	−1·53	−1·78	−1·21	−0·96					
	−2·17	−2·20	−2·20	−1·99	−1·66	−1·93	−1·31	1·04					

made during the Month of January, 1846.

X=8·077. Zero from the 26th to the 31st. Scale Divisions 94·67. Thermometer 80°.													
	611·6	606·9	598·9	584·6	565·0	553·4	548·3	8993·8	568·0				
	101·93	101·15	99·82	97·43	94·17	92·23	91·38	1513·71	94·67	−4·7	90·0	+·001122	
	−14·18	−12·72	−11·17	−9·05	−5·85	−3·72	−2·77						
	87·75	88·43	88·65	88·38	88·32	88·51	88·61						
	0·90	0·22	0·00	0·27	0·33	0·14	0·04						
	·00022	·00005	0·00	·00006	·00008	·00003	·00001						
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	544·4	535·6	526·3	513·6	494·4	481·6	475·9	8051·7	508·7				
	90·73	89·27	87·72	85·60	82·40	80·27	79·32	1354·77	84·75				
	−14·18	−12·72	−11·17	−9·05	−5·85	−3·72	−2·77						

Table B.

Observatory at Pulo Booaya.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					k=·000415987 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer.
Sums	.....	.....	237·4	235·5	231·6	233·0	230·3	233·4	239·7	250·7	335·8
Means of 3 & 4 days	.....	.....	79·13	78·50	77·20	77·67	76·77	77·80	79·90	83·57	83·95
Temp. corrections ...	.....	.....	0·00	−0·24	−0·60	−2·67	−3·67	−4·87	−5·64	−7·10	−5·87
Corrected means ...	.....	.....	79·13	78·26	76·60	75·00	73·10	72·93	74·26	76·47	78·08
Oscillations & diffs.	.....	.....	2·28	3·15	4·81	6·41	8·31	8·48	7·15	4·94	3·33
$\frac{\delta X}{X}$	.....	.....	·00055	·00076	·00116	·00154	·00200	·00204	·00172	·00119	·00080
											Thermometer of Bifilar.
Sums	.....	.....	240·4	241·1	242·2	248·4	251·4	255·0	257·3	261·7	344·0
Means of 3 & 4 days	.....	.....	80·13	80·37	80·73	82·80	83·80	85·00	85·77	87·23	86·00
Differences & corrs...	.....	.....	0·00	−0·24	−0·60	−2·67	−3·67	−4·87	−5·64	−7·10	−5·87

Observatory at Padang.—Hourly observations

					k=·000416 × cot 60°=·0002402. q =·0002402.						Bifilar Magnetometer.
Sums	1302·8	1302·6	1304·2	1195·6	1309·3	1340·8	1369·4	1386·2	1390·3	1413·6	1444·0
Means of 3 & 4 days	100·22	100·20	100·31	99·63	100·72	103·13	105·34	106·63	106·95	108·74	111·08
Temp. corrections ...	0·58	0·36	0·14	0·00	2·03	6·44	10·77	14·24	15·76	17·10	17·31
Corrected means ...	99·64	99·84	100·17	99·63	98·69	96·69	94·57	92·39	91·19	91·64	93·77
Oscillations & diffs.	3·81	3·61	3·28	3·82	4·76	6·76	8·88	11·06	12·26	11·81	9·68
$\frac{\delta X}{X}$	·00091	·00087	·00079	·00092	·00114	·00162	·00213	·00266	·00294	·00289	·00233
											Thermometer of Bifilar.
Sums	948·8	945·7	942·9	868·7	967·5	1024·8	1081·1	1126·2	1145·9	1163·4	1166·1
Means of 13 days ...	72·97	72·75	72·53	72·39	74·42	78·83	83·16	86·63	88·15	89·49	89·70
Differences & corrs.	0·58	0·36	0·14	0·00	2·03	6·44	10·77	14·24	15·76	17·10	17·31

Table B.

made during the Month of February 1846.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 6th to the 9th. Scale Divisions 81·81. Thermometer 80°.													
	342·7	350·1	351·9	341·0	331·3	331·0	247·2	.....	4522·6	330·1			
	85·68	87·53	87·98	85·25	82·83	82·75	82·40	.....	1308·91	81·81	−4·01	77·80	+ ·000963
	−7·07	−8·12	−6·57	−4·59	−2·22	−1·77	−1·07	.....					
	78·61	79·41	81·41	80·66	80·61	80·98	81·33	.....					
	2·80	2·00	0·00	0·75	0·80	0·43	0·08	.. ...					
	·00067	·00048	0·00	·00018	·00019	·00010	·00002	.....					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	348·8	353·0	346·8	338·9	329·4	327·6	162·4	.....	.....	4548·4	337·6	.....	
	87·20	88·25	86·70	84·72	82·35	81·90	81·20	.....	.....	1344·15	84·01	−4·01	
	−7·07	−8·12	−6·57	−4·59	−2·22	−1·77	−1·07	.....	.....				

made during the Month of October, 1847.

X=7·962. Zero from the 16th to the 31st. Scale Divisions 106·42. Thermometer 80°.													
	1476·8	1473·1	1482·8	1444·3	1385·0	1389·2	1393·7	1376·4	26180·1	1383·5			
	113·60	113·32	114·06	111·10	106·54	106·86	107·21	105·88	2021·52	106·42	−0·72	105·70	+ ·000173
	16·78	14·13	12·73	9·84	6·83	5·02	3·76	2·89					
	96·82	99·19	101·33	101·26	99·71	101·84	103·45	102·99					
	6·63	4·26	2·12	2·19	3·74	1·61	0·00	0·46					
	·00159	·00102	·00051	·00053	·00090	·00039	0·00	·00011					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	1159·2	1137·8	1106·5	1069·0	1029·8	1006·3	989·9	978·7	19858·3	1049·3			
	89·17	87·52	85·12	82·23	79·22	77·41	76·15	75·28	1533·12	80·72			
	16·78	14·13	12·73	9·84	6·83	5·02	3·76	2·89					

TABLE B.

Observatory at Padang.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$k = \cdot000416 \times \cot 60° = \cdot0002402.$ $q = \cdot0002402.$ Bifilar Magnetometer.						
Sums	2525·1	2624·7	2516·4	2608·9	2629·1	2705·4	2785·3	2825·2	2891·2	2941·9	2975·4
Means of 26 days ...	101·00	100·95	100·66	100·34	101·12	104·05	107·13	108·66	111·20	113·15	114·44
Temp. corrections ...	0·27	0·09	0·00	0·11	2·25	6·47	11·06	13·19	15·31	16·62	16·85
Corrected means ...	100·73	100·86	100·66	100·23	98·87	97·58	96·07	95·47	95·89	96·53	97·59
Oscillations & diffs.	1·02	0·89	1·09	1·52	2·88	4·17	5·68	6·28	5·86	5·22	4·16
$\frac{\delta X}{X}$	·00024	·00021	·00026	·00036	·00069	·00100	·00136	·00151	·00141	·00125	·00100
											Thermometer of Bifilar.
Sums	1828·5	1897·0	1821·7	1897·4	1953·1	2062·8	2182·2	2237·6	2292·7	2326·7	2332·7
Means of 26 days ...	73·14	72·96	72·87	72·98	75·12	79·34	83·93	86·06	88·18	89·49	89·72
Differences & corrs. .	0·27	0·09	0·00	0·11	2·25	6·47	11·06	13·19	15·31	16·62	16·85

Observatory at Padang.—Hourly observations

					$k = \cdot000415987 \times \cot 60° = \cdot0002402.$ $q = \cdot0002402.$ Bifilar Magnetometer.						
Sums	2814·5	2794·7	2774·5	2768·6	2766·1	2821·2	2927·7	2994·3	3045·4	3116·6	3162·0
Means of 26 days ...	108·25	107·49	106·71	106·48	106·39	108·51	112·60	115·17	117·13	119·87	121·62
Temp. corrections ...	0·61	0·22	0·00	0·01	1·03	4·71	9·49	13·36	15·61	17·95	18·63
Corrected means ...	107·64	107·27	106·71	106·47	105·36	103·80	103·11	101·81	101·52	101·92	102·99
Oscillations & diffs.	0·00	0·37	0·93	1·17	2·28	3·84	4·53	5·83	6·12	5·72	4·65
$\frac{\delta X}{X}$	·000	·00009	·00022	·00028	·00055	·00092	·00109	·00140	·00147	·00137	·00112
											Thermometer of Bifilar.
Sums	1914·9	1904·8	1899·1	1899·2	1925·9	2021·6	2145·8	2246·3	2304·8	2365·7	2383·5
Means of 26 days ...	73·65	73·26	73·04	73·05	74·07	77·75	82·53	86·40	88·65	90·99	91·67
Differences & corrs. .	0·61	0·22	0·00	0·01	1·03	4·71	9·49	13·36	15·61	17·95	18·63

TABLE B.

made during the Month of November, 1847.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 1st to the 30th. Scale Divisions 107·32. Thermometer 80°.													
	2977·4	2935·2	2927·8	2877·8	2811·4	2774·6	2747·5	2721·0	52801·3	2790·0			
	114·52	112·89	112·61	110·68	108·13	106·72	105·67	104·65	2038·57	107·32	−0·93	106·39	+ ·000223
	15·64	14·10	12·08	9·67	6·79	5·16	3·92	2·96					
	98·88	98·79	100·53	101·01	101·34	101·56	101·75	101·69					
	2·87	2·96	1·22	0·74	0·41	0·19	0·00	0·06					
	·00069	·00071	·00029	·00018	·00010	·00004	·0000	·0000					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	2301·3	2261·3	2208·8	2146·1	2071·2	2028·9	1996·7	1971·6	39818·3	2104·1			
	88·51	86·97	84·95	82·54	79·66	78·03	76·79	75·83	1537·07	80·93	−0·93		
	15·64	14·10	12·08	9·67	6·79	5·16	3·92	2·96					

made during the Month of December, 1847.

Zero from the 16th to the 31st, 113·24. Thermometer 80°.													
	3162·7	3128·9	3070·3	3021·5	2958·6	2898·9	2875·2	2839·6	55941·3	2944·2			
	121·64	120·34	118·09	116·21	113·79	111·50	110·58	109·22	2151·59	113·24	−1·10	112·14	+ ·000264
	17·46	15·09	12·09	9·87	6·73	4·46	3·36	2·36					
	104·18	105·25	106·00	106·34	107·06	107·04	107·22	106·86					
	3·46	2·41	1·64	1·30	0·58	0·60	0·42	0·78					
	·00085	·00058	·00039	·00031	·00014	·00014	·00010	·00019					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	2353·0	2291·5	2213·5	2155·7	2074·1	2015·1	1986·5	1960·3	40061·3	2108·4			
	90·50	88·13	85·13	82·91	79·77	77·50	76·40	75·40	1540·80	81·10	−1·10		
	17·46	15·09	12·09	9·87	6·73	4·46	3·36	2·36					

TABLE B.

Observatory at Padang.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					k=·00015987 × cot 60°=·0002402. q =·0002402. Bifilar Magnetometer.						
Sums	1667·1	1668·8	1665·0	1656·4	1659·9	1693·8	1726·2	1751·1	1780·8	1808·1	1849·4
Means of 13 days	128·24	128·37	128·08	127·42	127·68	130·29	132·78	134·70	136·98	139·08	142·26
Temp. corrections	0·55	0·33	0·08	0·00	0·81	4·51	9·14	12·36	14·66	16·25	18·22
Corrected means	127·69	128·04	128·00	127·42	126·87	125·78	123·64	122·34	122·32	122·83	124·04
Oscillations & diffs.	2·35	2·00	2·04	2·62	3·17	4·26	6·40	7·70	7·72	7·21	6·00
$\frac{\delta X}{X}$	·00056	·00048	·00049	·00063	·00076	·00102	·00154	·00185	·00185	·00173	·00144
										Thermometer of Bifilar.	
Sums	957·8	955·0	951·7	950·7	961·2	1009·3	1069·5	1111·4	1141·3	1162·0	1187·5
Means of 13 days	73·68	73·46	73·21	73·13	73·94	77·64	82·27	85·49	87·79	89·38	91·35
Differences & corrs.	0·55	0·33	0·08	0·00	0·81	4·51	9·14	12·36	14·66	16·25	18·22

Observatory at Bencoolen.—Hourly observations

					k=·000415987 × cot 60°=·0002402. q =·0002402. Bifilar Magnetometer.						
Sums	395·8	394·8	394·4	393·7	232·2	403·8	410·7	417·8	422·3	428·1	435·6
Means of 5 days	79·16	78·96	78·88	78·74	77·40	80·76	82·14	83·56	84·46	85·62	87·12
Temp. corrections	−0·42	−0·22	−0·04	0·00	−2·03	−5·10	−8·28	−11·18	−12·34	−13·28	−12·78
Corrected means	78·74	78·74	78·84	78·74	75·37	75·66	73·86	72·38	72·12	72·34	74·34
Oscillations & diffs.	1·30	1·30	1·20	1·30	4·67	4·38	6·18	7·66	7·92	7·70	5·70
$\frac{\delta X}{X}$	·00031	·00031	·00029	·00031	·00112	·00105	·00148	·00183	·00190	·00185	·00137
										Thermometer of Bifilar.	
Sums	367·3	366·3	365·4	365·2	225·2	390·7	406·6	421·1	426·9	431·6	429·1
Means of 5 days	73·46	73·26	73·08	73·04	75·07	78·14	81·32	84·22	85·38	86·32	85·82
Differences & corrs.	−0·42	−0·22	−0·04	0·00	−2·03	−5·10	−8·28	−11·18	−12·34	−13·28	−12·78

TABLE B.

made during the Month of January, 1848.

2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
X=7·9456. Zero from the 16th to the 31st. Scale Divisions 134·80. Thermometer 80°.												
1861·6	1858·8	1841·4	1817·5	1776·0	1751·2	1736·1	1727·7	33296·9	1752·6			
143·20	142·98	141·65	139·81	136·62	134·71	133·55	132·90	2561·30	134·80	−1·21	133·59	+ ·000291
17·47	15·23	13·26	10·94	7·76	5·35	3·75	2·86					
125·73	127·75	128·39	128·87	128·86	129·36	129·80	130·04					
4·31	2·29	1·65	1·17	1·18	0·68	0·24	0·00					
·00103	·00055	·00040	·00022	·00028	·00016	·00006	0·00					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$												
1177·8	1148·7	1123·1	1092·9	1051·6	1020·2	999·4	987·9	20059·0	1055·9			
90·60	88·36	86·39	84·07	80·89	78·48	76·88	75·99	1543·00	81·21			
17·47	15·23	13·26	10·94	7·76	5·35	3·75	2·86					

made during the Months of August and September, 1847.

Zero from the 31st to the 4th. Scale Divisions 83·08. Thermometer 80°.												
429·8	431·0	436·7	431·0	422·8	417·8	414·9	413·3	7726·5	415·7			
85·96	86·20	87·34	86·20	84·56	83·56	82·98	82·66	1576·26	83·08	+0·54	83·62	− ·000130
−10·82	−9·16	−9·66	−8·28	−6·06	−4·66	−3·32	−2·62					
75·14	77·04	77·68	77·92	78·50	78·90	79·66	80·04					
4·90	3·00	2·36	2·12	1·54	1·14	0·38	0·00					
·00118	·00072	·00057	·00075	·00037	·00027	·00009	0·00					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$												
419·3	411·0	413·5	406·6	395·5	388·5	381·8	378·3	7389·9	397·3			
83·86	82·20	82·70	81·32	79·10	77·70	76·36	75·66	1508·01	79·46	+0·54		
−10·82	−9·16	−9·66	−8·28	−6·06	−4·66	−3·32	−2·62					

TABLE B.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
						$k = \cdot000415987 \times \cot 60° = \cdot0002402.$ $q = \cdot0002402.$ Bifilar Magnetometer.							
Sums	1544·3	1625·1	1612·0	1611·9	1605·8	1598·7	1587·5	1596·4	1619·1	1635·2	1658·3	1688·8	1713·3
Means of 19 days	85·79	85·53	84·84	84·84	84·52	84·14	83·55	84·02	85·22	86·06	87·28	88·88	90·17
Temp. corrections	−1·89	−1·45	−1·10	−0·69	−0·51	−0·35	0·00	−1·43	−3·90	−6·23	−8·29	−9·94	−10·83
Corrected means	83·90	84·08	83·74	84·15	84·01	83·79	83·55	82·59	81·32	79·83	78·99	78·94	79·34
Oscillations & diffs.	0·25	0·07	0·41	0·00	0·14	0·36	0·60	1·56	2·83	4·32	5·16	5·21	4·81
$\frac{\delta X}{X}$	·00006	·00002	·00009	0·00	·00003	·00009	·00014	·00037	·00068	·00104	·00124	·00125	·00115
													Thermometer of Bifilar.
Sums	1392·9	1461·9	1455·2	1447·4	1444·0	1440·9	1434·4	1461·4	1508·5	1552·7	1591·9	1623·2	1640·0
Means of 19 days	77·38	76·94	76·59	76·18	76·00	75·84	75·49	76·92	79·39	81·72	83·78	85·43	86·32
Differences & corrs.	−1·89	−1·45	−1·10	−0·69	−0·51	−0·35	0·00	−1·43	−3·90	−6·23	−8·29	−9·94	−10·83

Observatory at Batavia.—Hourly observations

						$k = \cdot000415987 \times \cot 60° = \cdot0002402.$ $q = \cdot0002402.$ Bifilar Magnetometer.							
Sums	2159·8	2152·7	2145·5	2227·6	2218·2	2210·0	2202·2	2202·1	1636·8	1490·1	1520·7	1536·3	2350·0
Means of 25 days	86·39	86·11	85·82	85·68	85·32	85·00	84·70	84·70	86·15	87·65	89·45	90·37	90·38
Temp. corrections	−1·49	−1·18	−0·87	−0·57	−0·28	−0·13	0·00	−0·97	−3·43	−6·05	−8·39	−9·52	−9·19
Corrected means	84·90	84·93	84·95	85·11	85·04	84·87	84·70	83·73	82·72	81·60	81·06	80·85	81·19
Oscillations & diffs.	0·88	0·85	0·83	0·67	0·74	0·91	1·08	2·05	3·06	4·18	4·72	4·93	4·59
$\frac{\delta X}{X}$	·00021	·00020	·00020	·00016	·00018	·00022	·00026	·00049	·00073	·00100	·00113	·00120	·00110
													Thermometer of Bifilar.
Sums	1927·1	1919·3	1911·6	1980·2	1972·7	1968·7	1965·3	1990·5	1501·4	1387·9	1427·7	1446·9	2204·4
Mean of 25 days	77·08	76·77	76·46	76·16	75·87	75·72	75·59	76·56	79·02	81·64	83·98	85·11	84·78
Differences & corrs.	−1·49	−1·18	−0·87	−0·57	−0·28	−0·13	0·00	−0·97	−3·43	−6·05	−8·39	−9·52	−9·19

TABLE B.

made during the Month of November, 1846.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Temp. Corrs	Corr. Means.	$\frac{\delta X}{X}$
Zero from the 9th to the 30th. Scale Divisions 87·33. Thermometer 80°.																
	1729·1	1739·1	1741·1	1736·1	1721·8	1696·6	1674·3	1658·0	1650·7	1647·8	1642·3	39733·3	1659·0			
	91·00	91·53	91·64	91·37	90·62	89·29	88·12	87·26	86·88	86·73	86·44	2095·72	87·33	−0·32	87·01	+·000077
	−10·65	−10·59	−9·69	−8·63	−7·19	−5·54	−4·57	−3·81	−3·19	−2·81	−2·46					
	80·35	80·94	81·95	82·74	83·43	83·75	83·55	83·45	83·69	83·92	83·98					
	3·80	3·21	2·20	1·41	0·72	0·40	0·60	0·70	0·46	0·23	0·17					
	·00091	·00077	·00053	·00034	·00017	·00009	·00014	·00017	·00011	·00005	·00004					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$																
	1636·7	1635·5	1618·5	1598·2	1570·9	1539·6	1521·2	1506·7	1495·0	1487·7	1481·1	36545·5	1525·8			
	86·14	86·08	85·18	84·12	82·68	81·03	80·06	79·30	78·68	78·30	77·95	1927·50	80·32	−0·32		
	−10·65	−10·59	−9·69	−8·63	−7·19	−5·54	−4·57	−3·81	−3·19	−2·81	−2·46					

made during the Month of December, 1846.

Zero from the 1st to the 31st. Scale Divisions 88·44. Thermometer 80°.																
	2387·3	2409·7	2420·5	2415·8	2384·5	2254·8	2237·1	1690·4	1326·8	1316·0	1308·2	48203·1	2299·2			
	91·82	92·68	93·10	92·92	91·71	90·19	89·48	88·97	88·45	87·73	87·21	2121·98	88·44	+0·12	88·56	−·000030
	−9·51	−9·41	−8·88	−8·18	−6·49	−4·76	−3·88	−3·19	−2·74	−2·40	−1·87					
	82·31	83·27	84·22	84·74	85·22	85·43	85·60	85·78	85·71	85·33	85·34					
	3·47	2·51	1·56	1·04	0·56	0·35	0·18	0·00	0·07	0·45	0·44					
	·00083	·00060	·00037	·00025	·00013	·00008	·00004	0·00	·00002	·00011	·00011					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$																
	2212·7	2209·9	2196·1	2178·1	2134·1	2008·8	1986·7	1496·8	1174·9	1169·9	1161·9	43533·6	2075·8			
	85·10	85·00	84·47	83·77	82·08	80·35	79·47	78·78	78·33	77·99	77·46	1917·54	79·88	+0·12		
	−9·51	−9·41	−8·88	−8·18	−6·49	−4·76	−3·88	−3·19	−2·74	−2·40	−1·87					

TABLE B.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
$k = \frac{\cdot000415987 \times \cot 60°}{q} = \frac{\cdot0002402.}{\cdot0002402.}$ Bifilar Magnetometer.													
Sums	1657·2	1651·3	1637·4	2254·8	2242·8	2230·7	2221·1	2218·7	2237·1	2251·1	2259·7	2278·2	2316·3
Means of 25 days	92·07	91·74	90·97	90·19	89·71	89·23	88·84	88·75	89·48	90·04	90·39	91·13	92·65
Temp. corrections	−2·71	−2·19	−1·59	−0·93	−0·63	−0·30	0·00	−0·82	−1·68	−4·82	−6·53	−7·86	−8·38
Corrected means	89·36	89·55	89·38	89·26	89·08	88·93	88·84	87·93	87·80	85·22	83·86	83·27	84·27
Oscillations & diffs.	0·45	0·26	0·43	0·55	0·73	0·88	0·97	1·88	2·01	4·59	5·95	6·54	5·54
$\frac{\delta X}{X}$	·00011	·00006	·00010	·00013	·00017	·00021	·00023	·00045	·00048	·00088	·00143	·00157	·00133
Thermometer of Bifilar.													
Sums	1398·8	1389·4	1378·6	1898·3	1890·7	1882·5	1874·9	1895·5	1942·0	1995·4	2038·3	2071·5	2097·1
Means of 25 days	77·71	77·19	76·59	75·93	75·63	75·30	75·00	75·82	77·68	79·82	81·53	82·86	83·88
Differences & corrs.	−2·71	−2·19	−1·59	0·93	0·63	0·30	0·00	0·82	1·68	4·82	6·53	7·86	8·38

Observatory at Batavia.—Hourly observations

$k = \frac{\cdot000415987 \times \cot 60°}{q} = \frac{\cdot0002402.}{\cdot0002402.}$ Bifilar Magnetometer.													
Sums	1539·0	1535·8	1531·2	2297·9	2295·9	2287·6	2278·3	2274·9	2276·1	2291·4	2306·2	2323·4	2355·2
Means of 24 days	96·19	95·99	95·70	95·75	95·66	95·32	94·93	94·79	94·84	95·48	96·09	96·81	98·13
Temp. corrections	−1·33	−1·15	−0·89	−0·53	−0·34	−0·19	0·00	−0·36	−1·66	−3·81	−5·48	−6·84	−7·90
Corrected means	94·86	94·84	94·81	95·22	95·32	95·13	94·93	94·43	93·18	91·67	90·61	89·97	90·23
Oscillations & diffs.	1·38	1·40	1·43	1·02	0·92	1·11	1·31	1·81	3·06	4·57	5·63	6·27	6·01
$\frac{\delta X}{X}$	·00033	·00034	·00034	·00024	·00022	·00027	·00031	·00043	·00073	·00110	·00135	·00151	·00144
Thermometer of Bifilar.													
Sums	1235·5	1232·7	1228·5	1834·0	1829·4	1826·0	1821·4	1830·0	1861·2	1912·8	1952·8	1985·5	2011·0
Means of 24 days	77·22	77·04	76·78	76·42	76·23	76·08	75·89	76·25	77·55	79·70	81·37	82·73	83·79
Differences & corrs.	−1·33	−1·15	−0·89	−0·53	−0·34	−0·19	0·00	−0·36	−1·66	−3·81	−5·48	−6·84	−7·90

TABLE B.

made during the Month of January, 1847.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\partial X}{X}$
Zero from the 1st to the 30th. Scale Divisions 92·64. Thermometer 80°.															
2359·4	2386·6	2419·9	2436·7	2432·0	2409·9	2378·8	1892·5	1696·5	1686·4	1675·3	51230·4	2313·9			
94·38	95·46	96·80	97·47	97·28	96·40	95·15	94·63	94·25	93·69	93·07	2223·77	92·64	−0·04	92·60	+·000010
−9·81	−9·97	−9·92	−9·48	−8·71	−7·20	−5·63	−5·04	−4·63	−3·88	−3·37					
84·57	85·49	86·88	87·99	88·57	89·20	89·52	89·59	89·62	89·81	89·70					
5·24	4·32	2·93	1·82	1·24	0·61	0·29	0·22	0·19	0·00	0·11					
·00126	·00104	·00070	·00044	·00030	·00015	·00007	·00005	·00004	0·00	·00026					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$															
2120·3	2124·2	2123·1	2112·1	2092·7	2054·9	2015·8	1600·9	1433·3	1419·8	1410·7	44260·8	1998·3			
84·81	84·97	84·92	84·48	83·71	82·20	80·63	80·04	79·63	78·88	78·37	1917·58	80·04	−0·04		
9·81	9·97	9·92	9·48	8·71	7·20	5·63	5·04	4·63	3·88	3·37					

made during the Month of February, 1847.

Zero from the 1st to the 28th. Scale Divisions 97·70. Thermometer 80°.															
2385·1	2417·1	2431·4	2438·0	2424·1	2410·5	2395·0	2384·0	2273·8	1364·8	1360·8	51877·5	2348·0			
99·38	100·71	101·31	101·58	101·00	100·44	99·79	99·33	98·86	97·49	97·20	2342·77	97·70	+0·31	98·01	−·000074
−8·34	−8·52	−8·09	−6·97	−5·72	−4·73	−3·90	−3·09	−2·83	−2·56	−2·07					
91·04	92·19	93·22	94·61	95·28	95·71	95·89	96·24	96·03	94·93	95·13					
5·20	4·05	3·02	1·63	0·96	0·53	0·35	0·00	0·21	1·31	1·11					
·00125	·00097	·00073	·00039	·00023	·00013	·00008	0·00	·00005	·00031	·00027					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$															
2021·5	2025·9	2015·6	1988·7	1958·6	1934·9	1915·0	1895·5	1810·5	1098·3	1091·4	42316·7	1913·7			
84·23	84·41	83·98	82·86	81·61	80·62	79·79	78·98	78·72	78·45	77·96	1908·66	79·69	+0·31		
−8·34	−8·52	−8·09	−6·97	−5·72	−4·73	−3·90	−3·09	−2·83	−2·56	−2·07					

TABLE B.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$k = 000415987 \times \cot 60° = \cdot0002402.$ $q = \cdot0002402.$						Bifilar Magnetometer.
Sums	2704·4	2688·8	2674·3	2663·6	2663·3	2665·2	2686·0	2706·6	2725·7	2739·0	2765·7
Means of 27 days	100·16	99·59	99·05	98·65	98·64	98·71	99·48	100·24	100·95	101·44	102·43
Temp. corrections	−1·00	−0·68	−0·23	−0·00	−0·58	−2·43	−4·67	−6·29	−7·55	−8·38	−8·69
Corrected means	99·16	98·91	98·82	98·65	98·06	96·28	94·81	93·95	93·40	93·06	93·74
Oscillations & diffs.	0·00	0·25	0·34	0·51	1·10	2·88	4·35	5·21	5·76	6·10	5·42
$\frac{\delta X}{X}$	0·00	·00006	·00008	·00012	·00026	·00069	·00104	·00125	·00138	·00146	·00130
											Thermometer of Bifilar.
Sums	2092·9	2084·2	2072·0	2065·9	2081·3	2131·4	2191·9	2235·7	2269·6	2292·1	2300·4
Means of 27 days	77·51	77·19	76·74	76·51	77·09	78·94	81·18	82·80	84·06	84·89	85·20
Differences & corrs.	−1·00	−0·68	−0·23	0·00	−0·58	−2·43	−4·67	−6·29	−7·55	−8·38	8·69

Observatory at Batavia.—Hourly observations

					$k = \cdot00041598 \times \cot 60° = \cdot0002402.$ $q = \quad = \cdot0002402.$						Bifilar Magnetometer.
Sums	2734·8	2718·2	2703·7	2680·4	2683·6	2704·3	2626·1	2751·2	2764·7	2804·5	2841·9
Means of 26 days	105·18	104·55	103·99	103·09	103·22	104·01	105·04	105·82	106·33	107·87	109·30
Temp. corrections	−1·37	−0·72	−0·22	0·00	−1·42	−3·59	−5·39	−8·33	−9·48	−10·20	−10·14
Corrected means	103·81	103·83	103·77	103·09	101·80	100·42	99·65	97·49	96·85	97·67	99·16
Oscillations & diffs.	0·56	0·54	0·60	1·28	2·57	3·95	4·72	6·88	7·52	6·70	5·21
$\frac{\delta X}{X}$	·00013	·00013	·00014	·00031	·00062	·00095	·00113	·00165	·00181	·00161	·00125
											Thermometer of Bifilar.
Sums	2000·8	1983·8	1970·8	1965·0	2001·9	2058·4	2049·2	2181·7	2211·5	2230·2	2228·7
Means of 26 days	76·95	76·30	75·80	75·58	77·00	79·17	81·97	83·91	85·06	85·78	85·72
Differences & corrs.	−1·37	−0·72	−0·22	0·00	−1·42	−3·59	−5·39	−8·33	−9·48	−10·20	−10·14

TABLE B.

made during the Month of March, 1847.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 1st to the 31st. Scale Divisions 101·77. Thermometer 80°.													
	2811·5	2854·0	2866·6	2855·2	2816·7	2795·9	2780·5	2640·7	52103·7	2742·4			
	104·13	105·70	106·17	105·75	104·32	103·55	102·98	101·57	1933·51	101·77	−1·31	100·46	+·000315
	−8·93	−8·90	−8·35	−7·34	−5·56	−4·64	−3·87	−2·95					
	95·20	96·72	97·82	98·41	98·76	98·91	99·11	98·62					
	3·96	2·44	1·34	0·75	0·40	0·25	0·05	0·54					
	·00095	·00059	·00032	·00018	·00010	·00006	·00001	·00013					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	2306·8	2308·3	2291·3	2264·0	2215·9	2191·1	2170·3	2065·9	41631·0	2195·6			
	85·44	85·49	84·86	83·85	82·07	81·15	80·38	79·46	1544·81	81·31	−1·31		
	−8·93	−8·98	−8·35	−7·34	−5·56	−4·64	−3·87	−2·95					

made during the Month of April, 1847.

Zero from the 1st to the 30th. Scale Divisions 107·40. Thermometer 80°.													
	2888·2	2814·2	2930·7	2906·4	2212·4	2192·0	2164·1	2142·9	50264·3	2790·4			
	111·08	112·57	112·72	111·78	110·62	109·60	108·21	107·15	2042·13	107·40	−1·25	106·15	·000300
	−9·96	−9·48	−8·90	−7·70	−6·25	−5·27	−4·22	−3·52					
	101·12	103·09	103·82	104·08	104·37	104·33	103·99	103·63					
	3·25	1·28	0·55	0·29	0·00	0·04	0·38	0·74					
	·00078	·00031	·00013	·00007	·00024	·00001	·00009	·00018					
$\frac{q}{k}=\frac{\cdot0002402}{\cdot0002402}=1.$													
	2224·0	2126·4	2196·5	2165·3	1636·5	1616·9	1596·0	1581·9	38025·5	2112·9			
	85·54	85·06	84·48	83·28	81·83	80·85	79·80	79·10	1543·18	81·25	−1·25		
	−9·96	−9·48	−8·90	−7·70	−6·25	−5·27	−4·22	−3·52					

TABLE B.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \frac{\cdot 0002402}{\cdot 0002402}$. Bifilar Magnetometer.						
Sums	2849·3	2831·1	2811·1	2792·1	2802·8	2840·4	2460·0	2926·6	2947·9	2987·0	3012·5
Means of 26 days	109·59	108·89	108·12	107·39	107·80	109·25	111·82	112·56	113·38	114·88	115·87
Temp. corrections	−1·47	−0·95	0·40	0·00	−1·43	−4·58	−8·43	−9·70	−11·12	−12·36	−11·96
Corrected means	108·12	107·94	107·72	107·39	106·37	104·67	103·39	102·86	102·26	102·52	103·91
Oscillations & diffs.	−0·75	0·93	1·15	1·48	2·50	4·20	5·48	6·01	6·61	6·35	4·96
$\frac{\partial X}{X}$	·00018	·00022	·00028	·00035	·00060	·00101	·00132	·00144	·00159	·00152	·00119
											Thermometer of Bifilar.
Sums	1976·6	1963·0	1948·6	1938·3	1975·6	2057·5	1825·5	2190·6	2227·3	2259·7	2249·2
Means of 26 days	76·02	75·50	74·95	74·55	75·98	79·13	82·98	84·25	85·67	86·91	86·51
Differences & corrs.	−1·47	−0·95	−0·40	0·00	−1·43	−4·58	−8·43	−9·70	−11·12	−12·36	−11·96

Observatory at Batavia.—Hourly observations

					$k = \frac{\cdot 000415987 \times \cot 60^\circ}{q} = \frac{\cdot 0002402}{\cdot 0002402}$. Bifilar Magnetometer.						
Sums	2953·1	2928·1	2897·6	2762·3	2785·6	2815·3	2418·3	2909·2	3059·5	3099·8	3120·4
Means of 26 days	113·58	112·62	111·45	110·49	111·42	112·61	115·16	116·37	117·67	119·22	120·02
Temp. corrections	−1·30	−0·68	−0·20	0·00	−1·82	−4·50	−8·37	−10·42	−11·89	−12·87	−12·90
Corrected means	112·28	111·94	111·25	110·49	109·60	108·11	106·79	105·95	105·78	106·35	107·12
Oscillations & diffs.	0·00	0·34	1·03	1·79	2·68	4·17	5·49	6·33	6·50	5·93	5·16
$\frac{\partial X}{X}$	·00000	·00008	·00025	·00043	·00064	·00100	·00132	·00152	·00156	·00142	·00124
											Thermometer of Bifilar.
Sums	1957·8	1941·8	1929·2	1850·0	1895·5	1962·6	1729·7	2110·5	2233·1	2258·7	2259·5
Means of 26 days	75·30	74·68	74·20	74·00	75·82	78·50	82·37	84·42	85·89	86·87	86·90
Differences & corrs.	−1·30	−0·68	−0·20	0·00	−1·82	−4·50	−8·37	−10·42	−11·89	−12·87	−12·90

TABLE B.

made during the Month of May, 1847.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$.
Zero from the 1st to the 31st. Scale Divisions 112·95. Thermometer 80°.													
	3031·2	2599·6	3076·7	3059·1	2898·7	2747·9	2727·1	2701·4	54102·5	2935·8			
	116·58	118·16	118·33	117·66	115·95	114·50	113·63	112·56	2146·92	112·95	−1·16	111·79	+ ·000279
	−11·05	−11·06	−10·41	−9·01	−7·08	−5·93	−5·05	−4·30					
	105·53	107·10	107·92	108·65	108·87	108·57	108·58	108·26					
	3·34	1·77	0·95	0·22	0·00	0·30	0·29	0·61					
	·00080	·00042	·00023	·00005	0·00	·00007	·00007	·00015					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$													
	2225·5	1883·4	2208·9	2172·5	2040·8	1931·6	1910·4	1892·4	38877·4	2109·7			
	85·60	85·61	84·96	83·56	81·63	80·48	79·60	78·85	1542·74	81·16	−1·16		
	−11·05	−11·06	−10·41	−9·01	−7·08	−5·93	−5·05	−4·30					

made during the Month of June, 1847.

Zero from the 1st to the 30th. Scale Divisions 116·43. Thermometer 80°.													
	3030·1	2558·3	3028·4	2886·5	2729·9	2468·3	2446·4	2428·1	53325·2	3027·1			
	121·20	121·82	121·14	120·27	118·69	117·54	116·50	115·62	2213·39	116·43	−1·03	115·40	+ ·000247
	−12·59	−12·16	−10·78	−9·41	−7·17	−6·24	−5·46	−5·41					
	108·61	109·66	110·36	110·86	111·52	111·30	111·04	110·21					
	3·67	2·62	1·92	1·42	1·66	0·98	1·14	2·07					
	·00088	·00063	·00046	·00034	·00040	·00023	·00027	·00050					
$\frac{q}{k}=\frac{\cdot 0002402}{\cdot 0002402}=1.$													
	2164·7	1809·4	2119·5	2001·8	1866·8	1685·0	1668·7	1667·7	37112·0	2104·8			
	86·59	86·16	84·78	83·41	81·17	80·24	79·46	79·41	1540·17	81·03	−1·03		
	−12·59	−12·16	−10·78	−9·41	−7·17	−6·24	−5·46	−5·41					

TABLE B.

Observatory at Cocos Island.—Hourly observations made

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.	1.
					$\frac{k}{q}$=·000415987 × cot 60°=·0002402. =·0002402.						Bifilar Magnetometer.
Sums	2152·6	2137·9	2130·3	2121·6	2091·7	2092·3	2103·7	2111·6	2124·5	2126·3	2154·3
Means of 27 days	79·73	79·18	78·90	78·58	77·47	77·49	77·91	78·21	78·69	78·75	79·79
Temp. corrections	−0·32	−0·16	−0·11	0·00	−0·42	−1·61	−3·31	−4·35	−5·62	−5·99	−5·93
Corrected means	79·41	79·02	78·79	78·58	77·05	75·88	74·60	73·86	73·07	72·76	73·86
Oscillations & diffs.	0·98	1·37	1·60	1·81	3·34	4·51	5·79	6·53	7·32	7·63	6·53
$\frac{\delta X}{X}$	·00023	·00033	·00038	·00043	·00080	·00108	·00139	·00157	·00176	·00183	·00157
											Thermometer of Bifilar.
Sums	2079·6	2075·2	2073·9	2070·9	2082·3	2114·3	2160·2	2188·4	2222·6	2232·7	2231·1
Means of 27 days	77·02	76·86	76·81	76·70	77·12	78·31	80·01	81·05	82·32	82·69	82·63
Differences & corrs.	−0·32	−0·16	−0·11	0·00	−0·42	−1·61	−3·31	−4·35	−5·62	−5·99	−5·93

TABLE B.

during the Months of August and September, 1848.

	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Temp. Corrs.	Corrected Means.	$\frac{\delta X}{X}$
Zero from the 28th of August to the 27th of September. Scale Divisions 79·76. Thermometer 80°.													
	2179·2	2193·6	2204·5	2193·5	2183·1	2183·2	2192·5	2190·2	41872·4	2151·6			
	80·71	81·24	81·65	81·24	80·86	80·86	81·20	81·12	1513·58	79·76	+0·94	80·70	−·000226
	−5·10	−4·14	−3·28	−2·06	−1·20	−0·96	−0·83	−0·73					
	75·61	77·10	78·37	79·18	79·66	79·90	80·37	80·39					
	4·78	3·29	2·02	1·21	0·73	0·49	0·02	0·00					
	·00115	·00079	·00048	·00029	·00017	·00012	·00001	0·00					
$\frac{q}{k}=\frac{\cdot 000\,2402}{\cdot 000\,2402}=1.$													
	2208·5	2182·6	2159·4	2126·6	2103·4	2096·7	2093·3	2090·7	41513·7	2135·1			
	81·80	20·84	79·98	78·76	77·90	77·66	77·53	77·43	1503·42	79·07			
	−5·10	−4·14	−3·28	−2·06	−1·20	−0·96	−0·83	−0·73					

Table C.

Variation of the Dry Thermometer at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Moulmein	.....	.....	.....	0·5	0·2	0·0	0·1	2·9	10·5	14·2	18·8
Madras	.....	.....	.....	1·1	0·8	0·3	0·0	1·4	4·5	7·7	10·4
Nicobar	.....	.....	.....	0·0	0·6	0·8	0·9	2·0	6·6	9·0	12·8
Sambooanga	.....	.....	.....	0·2	0·1	0·3	0·0	4·7	9·6	10·8	11·2
Penang	.....	.....	.....	1·5	1·0	0·0	0·2	1·1	3·3	7·5	11·1
Pulo Dinding	.....	.....	.....	1·4	1·0	0·3	0·0	0·5	5·8	11·1	18·4
Sarawak	1·6	1·3	1·0	0·8	0·6	0·4	0·0	0·3	1·7	4·0	6·2
Keemah	.....	.....	.....	1·0	0·7	0·4	0·0	2·7	9·4	12 3	15·6
Pulo Peesang	.....	.....	.....	.....	0·8	0·0	0·2	1·0	2·0	5·0	9·2
Singapore	.....	.....	.....	1·3	1·1	0·9	0·3	0·0	0·8	2·0	5·5
Carimon	.....	.....	.....	.....	.....	0·6	0·0	2·4	5·5	8·0	9·8
Padang	.....	.....	.....	0·5	0·2	0·0	0·0	1·5	5·9	10·0	12·2
Bencoolen	.....	.....	.....	1·4	1·2	0·0	1·0	4·0	7·1	9·7	12·3
Batavia, Winter	1·8	1·5	1·1	0·7	0·4	0·2	0·0	1·2	3·4	5·8	7·6
Batavia, Spring	.....	.....	.....	1·4	0·9	0·3	0·0	1·2	4·1	7·6	9·6
Cocos	.....	.....	.....	0·4	0·3	0·3	0·0	0·4	1·7	3·5	4·8

Variation of the Dry Thermometer at

June 1846	1·5	1·1	0·8	0·6	0·4	0·4	0·0	0·5	2·0	4·3	6·7
July	1·8	1·5	1·2	0·9	0·7	0·6	0·0	0·3	1·6	3·8	5·7
August	1·6	1·3	1·0	0·8	0·6	0·3	0·0	0·2	1·5	4·0	6·1
Sums	4·9	3·9	3·0	2·3	1·7	1·3	0·0	1·0	5·1	12·1	18·5
Means and Variation	1·6	1·3	1·0	0·8	0·6	0·4	0·0	0·3	1·7	4·0	6·2

Variation of the Dry Thermometer at

October 1847	.....	.....	.....	0·5	0·3	0·1	0·0	2·0	6·5	10·5	12·6
November	.....	.....	.....	0·5	0·2	0·0	0·0	1·9	6·5	10·1	12·1
December	.....	.....	.....	0·6	0·3	0·0	0·0	1·2	5·5	9·9	12·7
January 1848	.....	.....	.....	0·5	0·2	0·0	0·0	0·9	5·2	9·6	11·6
Sums	.....	.....	.....	2·1	1·0	0·1	0·0	6·0	23·7	40·1	49·0
Means and Variation	.....	.....	.....	0·5	0·2	0·0	0·0	1·5	5·9	10·0	12·2

Variation of the Dry Thermometer at

November 1848	.....	.....	.....	1·1	0·9	0·8	0·5	0·0	0·6	1·6	2·4
December	.....	.....	.....	1·5	1·3	1·0	0·2	0·0	1·1	2·5	3·1
Sums	.....	.....	.....	2·7	2·2	1·8	0·7	0·0	1·7	4·1	5·5
Means and Variation	.....	.....	.....	1·3	1·1	0·9	0·3	0·0	0·8	2·0	2·7

TABLE C.

various Stations in the Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
21·9	24·3	23·7	24·0	20·4	18·8	15·7	9·8	6·6	4·7	4·0	.....	.....	11·7
12·7	14·5	15·5	15·1	13·7	12·2	9·6	7·2	5·4	4·5	3·9	.....	.....	7·4
13·5	13·7	14·6	12·5	12·2	11·6	10·3	7·4	5·5	4·6	3·4	.....	.....	7·5
10·0	12·4	13·3	14·0	13·5	12·2	10·1	7·8	7·1	5·5	4·6	.....	.....	7·7
13·1	12·0	11·4	10·5	10·7	9·9	7·9	5·8	4·7	4·2	3·4	.....	.....	6·3
22·2	20·5	21·8	18·5	16·4	13·1	9·1	5·4	4·3	4·0	3·3	.....	.....	9·3
8·0	9·6	10·2	10·4	9·5	8·3	7·1	5·1	3·6	2·9	2·6	2·2	1·9	4·1
17·1	18·6	14·1	12·6	11·6	10·7	8·5	6·8	5·6	4·7	4·0	.....	.....	8·1
12·0	13·5	13·7	9·7	7·3	6·7	4·2	3·1	2·9	3·0	2·1	.....	.....	5·7
3·4	3·9	3·8	3·4	3·2	3·0	2·6	2·4	2·2	2·0	1·6	.....	.....	2·2
12·8	12·2	13·0	13·3	11·1	10·0	8·0	4·7	3·7	2·8	.....	.....	.....	7·4
14·0	15·5	16·0	15·1	13·3	11·1	8·7	6·1	4·6	3·4	2·6	.....	.....	7·4
12·9	13·6	13·0	11·3	10·0	10·5	8·7	6·2	5·1	4·3	3·6	.....	.....	7·3
8·9	9·6	9·8	10·0	9·5	8·6	7·0	5·3	4·4	3·7	2·8	2·9	2·3	4·6
10·9	11·8	11·8	11·3	11·0	10·2	8·6	6·6	5·5	4·7	4·0	.....	.....	6·4
6·4	6·7	5·9	5·0	3·8	2·8	1·8	1·2	1·0	1·1	0·9	.....	.....	2·5

Sarawak in Borneo, Eastern Archipelago.

8·5	9·9	10·4	10·2	9·2	8·3	7·0	4·7	3·7	3·0	2·5	2·1	1·8	
7·6	9·1	9·3	9·8	8·7	8·3	7·3	5·4	3·6	3·0	2·7	2·3	2·0	
8·0	9·7	11·0	11·1	10·5	8·2	7·1	5·3	3·5	2·8	2·5	2·2	1·9	
24·1	28·7	30·7	31·1	28·4	24·8	21·4	15·4	10·8	8·8	7·7	6·6	5·7	
8·0	9·6	10·2	10·4	9·5	8·3	7·1	5·1	3·6	2·9	2·6	2·2	1·9	4·1

Padang, Sumatra, Eastern Archipelago.

14·0	14·6	14·3	14·1	12·4	10·4	8·1	6·3	4·9	3·4	2·8	.....	.....	
13·8	15·3	15·2	14·0	12·3	10·7	8·5	6·2	4·9	3·9	3·0	.....	.....	
14·4	16·8	16·9	15·9	13·9	10·7	8·5	5·7	4·1	3·2	2·1	.....	.....	
13·9	15·4	17·6	16·3	14·5	12·5	9·9	6·2	4·7	3·2	2·4	.....	.....	
56·1	62·1	64·0	60·3	53·1	44·3	35·0	24·4	18·6	13·7	10·3	.....	.....	
14·0	15·5	16·0	15·1	13·3	11·1	8·7	6·1	4·6	3·4	2·6	.....	.....	7·4

Singapore, Eastern Archipelago.

3·2	3·5	3·5	3·4	3·0	2·7	2·4	2·3	2·1	1·8	1·4	.....	.....	2·0
3·7	4·3	4·2	3·5	3·5	3·4	2·8	2·5	2·4	2·2	1·9	.....	.....	2·4
6·9	7·8	7·7	6·9	6·5	6·1	5·2	4·8	4·5	4·0	3·3	.....	.....	4·4
3·4	3·9	3·8	3·4	3·2	3·0	2·6	2·4	2·2	2·0	1·6	.....	.....	2·2

TABLE C.

Variation of the Dry Thermometer at Batavia

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
November ...1846.....	1·9	1·5	1·2	0·8	0·6	0·4	0·0	1·9	4·4	7·1	9·2
December	1·7	1·3	1·0	0·7	0·3	0·1	0·0	1·3	3·9	6·7	8·9
January .....1847.....	2·5	2·0	1·4	0·9	0·5	0·2	0·0	1·1	3·3	5·2	6·7
February	1·3	1·1	0·7	0·5	0·4	0·2	0·0	0·5	1·9	4·1	5·6
Sums	7·4	5·9	4·3	2·9	1·8	0·9	0·0	4·8	13·5	23·1	30·4
Means and Variation...	1·8	1·5	1·1	0·7	0·4	0·2	0·0	1·2	3·4	5·8	7·6

Variation of the Dry Thermometer at Batavia

March .....1847.....	.....	.....	.....	1·2	0·7	0·2	0·0	0·7	2·7	5·1	6·9
April	.....	.....	.....	1·7	1·0	0·4	0·0	1·3	3·9	6·9	9·1
May	.....	.....	.....	1·5	1·0	0·4	0·0	1·4	5·0	9·2	10·7
June	.....	.....	.....	1·4	0·9	0·4	0·0	1·4	4·8	9·3	11·7
Sums	.....	.....	.....	5·8	3·6	1·4	0·0	4·8	16·4	30·5	38·4
Means and Variation...	.....	.....	.....	1·4	0·9	0·3	0·0	1·2	4·1	7·6	9·6

Variation of the Wet Thermometer at

Moulmein	.....	.....	.....	0·7	0·6	0·0	0·1	1·9	5·5	6·7	7·9
Madras	.....	.....	.....	1·3	0·9	0·4	0·0	0·9	1·6	1·9	3·1
Nicobar	.....	.....	.....	0·0	0·5	0·5	0·5	1·7	5·1	6·1	8·2
Sambooanga	.....	.....	.....	0·0	0·0	0·4	0·0	3·1	6·1	7·5	7·2
Penang	.....	.....	.....	1·3	1·0	0·3	0·2	0·0	2·6	5·5	7·8
Pulo Dinding	.....	.....	.....	1·5	0·8	0·4	0·0	1·0	3·6	7·3	10·0
Sarawak.....	1·3	1·1	0·8	0·6	0·5	0·3	0·0	0·3	1·3	2·7	3·5
Keemah	.....	.....	.....	1·1	0·9	0·6	0·0	2·6	6·0	8·1	9·9
Pulo Peesang	.....	.....	.....	.....	0·5	0·0	0·1	0·8	1·3	3·0	5·0
Singapore	.....	.....	.....	0·9	0·8	0·7	0·2	0·0	0·4	1·0	1·3
Carimon.....	.....	.....	.....	.....	.....	0·1	0·0	1·4	2·7	3·7	4·1
Padang	.....	.....	.....	0·5	0·3	0·1	0·0	1·2	3·8	6·2	6·8
Bencoolen	.....	.....	.....	0·5	0·2	0·0	0·0	2·2	3·8	5·0	5·9
Batavia, Winter.....	1·1	1·0	0·7	0·5	0·3	0·1	0·0	0·7	1·9	2·8	3·3
Batavia, Spring.....	.....	.....	.....	0·9	0·6	0·2	0·0	0·9	2·3	3·7	4·2
Cocos.....	.....	.....	.....	0·1	0·1	0·1	0·0	0·2	1·0	2·2	2·9

Variation of the Wet Thermometer at

June .....1846.....	1·2	1·0	0·8	0·6	0·4	0·3	0·0	0·4	1·5	2·9	3·8
July	1·4	1·2	0·9	0·6	0·5	0·3	0·0	0·3	1·2	2·6	3·3
August	1·3	1·1	0·8	0·6	0·5	0·2	0·0	0·3	1·2	2·5	3·4
Sums	3·9	3·3	2·5	1·8	1·4	0·8	0·0	1·0	3·9	8·0	10·5
Means and Variation...	1·3	1·1	0·8	0·6	0·5	0·3	0·0	0·3	1·3	2·7	3·5

Table C.

in Java, Eastern Archipelago. Winter.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
10·6	11·6	11·1	11·3	10·2	9·2	7·3	5·0	4·5	3·8	1·3	2·9	2·5	5·1
10·0	9·5	9·5	9·5	9·4	8·1	6·3	4·6	3·7	3·0	2·6	2·3	1·7	4·4
8·0	9·2	10·2	10·4	10·5	10·0	8·8	7·0	5·7	5·0	4·5	3·8	3·2	5·2
7·0	8·2	8·6	8·9	8·1	7·0	5·7	4·5	3·8	3·1	2·8	2·5	1·9	3·9
35·6	38·5	39·4	40·1	38·2	34·3	28·1	21·1	17·7	14·9	11·2	11·5	9·3	18·6
8·9	9·6	9·8	10·0	9·5	8·6	7·0	5·3	4·4	3·7	2·8	2·9	2·3	4·6

in Java, Eastern Archipelago. Spring.

8·1	9·0	9·6	9·6	9·7	9·0	7·6	5·5	4·6	3·7	2·8	.....	.....	5·1
10·2	11·1	11·1	10·4	10·1	9·6	8·1	6·6	5·6	4·7	4·0	.....	.....	6·1
12·2	13·3	12·6	11·6	11·4	10·8	9·1	7·0	5·6	4·9	4·3	.....	.....	6·9
13·1	13·9	14·0	13·5	12·9	11·3	9·8	7·4	6·4	5·5	5·0	.....	.....	7·5
43·6	47·3	47·3	45·1	44·1	40·7	34·6	26·5	22·2	18·8	16·1	.....	.....	25·6
10·9	11·8	11·8	11·3	11·0	10·2	8·6	6·6	5·5	4·7	4·0	.....	.....	6·4

various stations in the Eastern Archipelago.

8·4	9·1	8·4	7·1	6·1	5·5	4·6	3·0	2·5	2·3	2·0	.....	.....	4·3
3·5	4·0	4·4	4·5	4·8	4·5	4·2	3·7	3·9	3·8	3·6	.....	.....	2·9
8·0	8·2	9·1	7·5	7·6	7·4	6·7	5·3	4·0	3·6	2·6	.....	.....	4·9
6·2	7·6	8·0	9·1	8·6	8·3	6·8	5·8	5·1	4·1	3·6	.....	.....	5·1
8·6	7·8	7·0	6·5	6·3	6·6	5·3	4·2	3·8	3·3	2·7	.....	.....	3·3
11·5	10·0	11·4	9·8	10·6	7·7	6·1	3·8	3·2	2·4	2·7	.....	.....	5·4
4·1	4·5	4·8	4·7	4·5	4·2	3·9	3·7	2·8	2·4	2·0	1·8	1·5	2·4
11·0	12·1	8·8	8·7	7·9	7·2	6·6	5·7	5·0	4·2	3·7	.....	.....	5·7
5·7	5·6	6·0	4·5	3·6	3·9	2·8	2·0	2·1	1·9	1·5	.....	.....	3·0
1·6	2·0	2·2	2·0	2·5	1·8	1·5	1·7	1·8	1·7	1·5	.....	.....	1·3
5·3	4·8	5·3	5·7	4·5	4·3	3·5	2·5	1·7	1·0	.....	.....	.....	3·2
7·8	8·5	8·8	8·3	7·6	6·9	5·9	4·7	4·1	3·2	2·8	.....	.....	4·6
6·2	6·8	6·9	6·5	5·4	5·7	5·1	3·7	2·6	1·9	1·6	.....	.....	3·7
3·8	4·0	4·1	4·1	4·0	3·5	3·1	2·6	2·5	2·2	2·1	2·0	1·6	2·2
4·6	4·9	4·9	4·9	4·7	4·4	3·9	3·3	2·9	2·6	2·1	.....	.....	3·0
4·0	4·1	3·6	3·3	2·4	1·8	1·0	0·7	0·7	0·6	0·5	.....	.....	1·5

Sarawak in Borneo, Eastern Archipelago.

4·3	4·8	5·0	4·7	4·6	4·3	3·7	3·3	2·9	2·4	1·9	1·7	1·3	
3·9	4·2	4·2	4·3	4·2	4·4	3·8	3·8	2·8	2·3	2·0	1·8	1·5	
4·0	4·5	5·1	5·1	4·7	4·0	4·1	3·9	2·8	2·4	2·2	1·8	1·6	
12·2	13·5	14·3	14·1	13·5	12·7	11·6	11·0	8·5	7·1	6·1	5·3	4·4	
4·1	4·5	4·8	4·7	4·5	4·2	3·9	3·7	2·8	2·4	2·0	1·8	1·5	2·4

Table C.

Variation of the Wet Thermometer at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
October .....1847.....	.....	.....	.....	0·7	0·5	0·2	0·0	1·7	4·2	6·7	6·9
November	.....	.....	.....	0·4	0·2	0·1	0·0	1·3	4·0	5·9	6·5
December	.....	.....	.....	0·5	0·2	0·0	0·0	1·0	3·9	6·1	7·3
January .....1848.....	.....	.....	.....	0·5	0·2	0·0	0·1	0·7	3·3	6·0	6·7
Sums	.....	.....	.....	2·1	1·1	0·3	0·1	4·7	15·4	24·7	27·4
Means and Variation...	.....	.....	.....	0·5	0·3	0·1	0·0	1·2	3·8	6·2	6·8

Variation of the Wet Thermometer at

November .....1848...	.....	.....	.....	0·9	0·7	0·6	0·4	0·0	0·4	0·9	1·3
December	.....	.....	.....	1·0	0·9	0·8	0·0	0·0	0·4	1·1	1·3
Sums	.....	.....	.....	1·9	1·6	1·4	0·4	0·0	0·8	2·0	2·6
Means and Variation...	.....	.....	.....	0·9	0·8	0·7	0·2	0·0	0·4	1·0	1·3

Variation of the Wet Thermometer

November ...1846.....	1·1	1·9	0·6	0·4	0·3	0·1	0·0	1·1	2·3	3·3	3·6
December	1·0	0.8	0·7	0·5	0·3	0·1	0·0	0·8	2·2	3·3	3·8
January .....1847.....	1·5	1·3	0·9	0·6	0·4	0·1	0·0	0·6	1·8	2·5	3·1
February	1·0	1·0	0·7	0·6	0·4	0·2	0·0	0·4	1·5	2·3	2·8
Sums	4·6	4·0	2·9	2·1	1·4	0·5	0·0	2·9	7·8	11·4	13·3
Means and Variation...	1·1	1·0	0·7	0·5	0·3	0·1	0·0	0·7	1·9	2·8	3·3

Variation of the Bulb Thermometer

March	.....	.....	.....	0·9	0·5	0·2	0·0	0·7	1·8	2·6	3·1
April	.....	.....	.....	1·3	0·6	0·1	0·0	1·0	2·3	3·7	4·3
May	.....	.....	.....	1·3	0·8	0·4	0·0	1·1	2·9	4·4	4·9
June	.....	.....	.....	0·1	0·7	0·2	0·0	0·8	2·4	4·3	4·5
Sums	.....	.....	.....	3·6	2·6	0·9	0·0	3·6	9·4	15·0	16·8
Means and Variation...	.....	.....	.....	0·9	0·6	0·2	0·0	0·9	2·3	3·7	4·2

Diurnal Variation of the Tension of Vapour

	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Moulmein	.....	.....	.....	·023	·022	·000	·002	·043	·105	·116	·121
Madras	.....	.....	.....	·044	·031	·017	·005	·024	·016	·019	·010
Nicobar	.....	.....	.....	·000	·012	·010	·009	·041	·123	·138	·185
Sambooanga	.....	.....	.....	·000	·001	·014	·002	·069	·138	·185	·168
Pulo Penang	.....	.....	.....	·027	·022	·006	·000	·021	·058	·131	·188
Pulo Dinding.....	.....	.....	.....	·040	·018	·011	·000	·031	·071	·165	·200
Sarawak.....	·033	·029	·022	·016	·012	·006	·000	·010	·033	·062	·075
Keemah	.....	.....	.....	·029	·025	·017	·000	·066	·126	·184	·223
Pulo Peesang.....	.....	.....	.....	.....	·009	·000	·002	·020	·028	·064	·103
Singapore	.....	.....	.....	·023	·019	·017	·004	·000	·006	·017	·021
Carimon.....	.....	.....	.....	.....	.....	·000	·004	·032	·051	·065	·064
Padang	.....	.....	.....	·012	·006	·002	·000	·026	·078	·133	·130
Bencoolen	.....	.....	.....	·014	·006	·000	·000	·055	·085	·107	·117
Batavia, Winter.....	·023	·021	·015	·011	·007	·001	·000	·013	·037	·047	·047
Batavia, Spring.....	.....	.....	.....	·029	·015	·005	·000	·021	·046	·063	·061
Cocos.....	.....	.....	.....	·000	·001	·001	000	·004	·019	·056	·059

TABLE C.

Padang in Sumatra, Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
7·9	8·2	8·2	8·2	7·5	6·9	6·3	5·2	4·3	3·3	3·1	.....	.....	.....
7·2	8·2	8·1	7·9	7·2	6·6	5·5	4·5	4·2	3·4	2·9	.....	.....	.....
8·1	8·8	9·2	8·5	7·4	6·3	5·5	4·5	3·6	2·7	2·4	.....	.....	.....
8·0	8·8	9·6	8·8	8·5	7·9	6·4	4·8	4·2	3·5	2·9	.....	.....	.....
31·2	34·0	35·1	33·4	30·6	27·7	23·7	19·0	16·3	12·9	11·3	.....	.....	.....
7·8	8·5	8·8	8·3	7·6	6·9	5·9	4·7	4·1	3·2	2·8	.....	.....	4·6

Singapore, Eastern Archipelago.

1·7	1·9	2·2	2·3	3·0	1·9	1·6	1·8	1·9	1·7	1·6	.....	.....	1·4
1·6	2·2	2·3	1·8	2·0	1·7	1·4	1·6	1·8	1·7	1·5	.....	.....	1·3
3·3	4·1	4·5	4·1	5·0	3·6	3·0	3·4	3·7	3·4	3·1	.....	.....	.....
1·6	2·0	2·2	2·0	2·5	1·8	1·5	1·7	1·8	1·7	1·5	.....	.....	1·3

at Batavia in Java, Eastern Archipelago. Winter.

4·3	4·8	4·4	4·6	4·5	3·9	3·6	2·9	2·8	2·4	2·1	2·0	1·6	2·4
4·3	4·0	4·1	4·0	3·8	3·2	2·6	2·2	2·1	1·9	1·7	1·7	1·3	2·0
3·4	3·7	4·2	4·2	4·3	4·1	3·8	3·0	2·8	2·7	2·5	2·3	2·0	2·4
3·2	3·4	3·7	3·7	3·3	2·9	2·6	2·3	2·3	1·9	2·0	1·9	1·6	2·0
15·2	15·9	16·4	16·5	15·9	14·1	12·6	10·4	10·0	8·9	8·3	7·9	6·5	8·8
3·8	4·0	4·1	4·1	4·0	3·5	3·1	2·6	2·5	2·2	2·1	2·0	1·6	2·2

at Batavia in Java, Eastern Archipelago. Spring.

3·5	3·8	3·9	4·2	4·2	3·9	3·3	2·7	2·3	2·0	1·3	.....	.....	2·4
4·6	4·8	4·7	4·6	4·4	4·1	3·6	3·1	2·6	2·3	1·7	.....	.....	2·8
5·5	5·6	5·6	5·5	5·3	5·2	4·6	3·9	3·7	3·3	3·0	.....	.....	3·5
4·8	5·3	5·4	5·3	5·1	4·6	4·3	3·7	3·2	2·9	2·6	.....	.....	3·2
18·4	19·5	19·6	19·6	19·0	17·8	15·8	13·4	11·8	10·5	8·6	.....	.....	11·9
4·6	4·9	4·9	4·9	4·7	4·4	3·9	3·3	2·9	2·6	2·1	.....	.....	3·0

at various Stations in the Eastern Archipelago.

in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·109	·114	·085	·024	·021	·015	·010	·010	·025	·039	·034	.....	.....	·043
·000	·001	·006	·015	·044	·075	·064	·071	·100	·105	·104	.....	.....	·035
·169	·175	·202	·159	·167	·166	·148	·122	·051	·083	·059	.....	.....	·105
·137	·171	·177	·219	·201	·202	·164	·146	·124	·100	·090	.....	.....	·117
·202	·177	·151	·141	·131	·152	·118	·095	·091	·076	·061	.....	.....	·094
·226	·176	·227	·190	·251	·161	·136	·084	·073	·045	·064	.....	.....	·104
·077	·077	·081	·077	·079	·082	·078	·092	·074	·062	·053	·046	·037	·049
·257	·291	·193	·205	·184	·162	·161	·143	·128	·106	·096	.....	.....	·129
·100	·079	·093	·077	·064	·083	·065	·044	·051	·042	.....	.....	.....	·056
·027	·038	·048	·039	·043	·038	·031	·041	·049	·045	·044	.....	.....	·027
·079	·065	·087	·090	·066	·070	·056	·051	·030	·011	.....	.....	.....	·050
·151	·165	·171	·168	·152	·147	·133	·113	·102	·082	·077	.....	.....	·093
·123	·140	·151	·154	·119	·127	·122	·091	·059	·041	·037	.....	.....	·079
·052	·052	·054	·053	·052	·044	·046	·043	·048	·045	·041	·044	·036	·033
·063	·064	·065	·072	·068	·065	·061	·059	·054	·050	·049	.....	.....	·043
·087	·088	·076	·074	·052	·039	·019	·013	·014	·003	·011	.....	.....	·032

TABLE C.

Diurnal Variation of the Tension of Vapour at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June .....1846.....	·031	·028	·023	·018	·012	·008	·000	·010	·038	·071	·077
July	·035	·030	·021	·013	·011	.006	·000	·009	·029	·061	·080
August	·034	·029	·022	·016	·014	·005	·000	·011	·031	·055	·069
Sums	·100	·087	·066	·047	·037	·019	·000	·030	·098	·187	·226
Means and Variation .	·033	·029	·022	·016	·012	·006	·000	·010	·033	·062	·075

Diurnal Variation of the

October.....1847.....	.....	.....	.....	·019	·015	·006	·000	·040	·085	·141	·125
November	.....	.....	.....	·010	·006	·004	·000	·028	·080	·117	·120
December	.....	.....	.....	·010	·002	·000	·000	·022	·084	·149	·143
January ...1848.....	.....	.....	.....	·013	·005	·000	·004	·018	·067	·127	·134
Sums	.....	.....	.....	·052	·028	·010	·004	·108	·316	·534	·522
Means and Variation .	.....	.....	.....	·012	·006	·002	·000	·026	·078	·133	·130

Diurnal Variation of the

November ...1848.....	.....	.....	.....	·024	·018	·015	·011	·000	·010	·018	·026
December	.....	.....	.....	·024	·022	·022	·000	·002	·005	·018	·018
Sums	.....	.....	.....	·048	·040	·037	·011	·002	·015	·036	·044
Means	.....	.....	.....	·024	·020	·018	·005	·001	·007	·018	·022
Variation	.....	.....	.....	·023	·019	·017	·004	·000	·006	·017	·021

Diurnal Variation of the

November ...1846.....	·022	·018	·011	·008	·006	·000	·000	·022	·042	·053	·042
December	·020	·016	·016	·013	·009	·003	·000	·016	·043	·057	·054
January .....1847.....	·029	·026	·019	·012	·008	·000	·005	·010	·032	·038	·046
February	·025	·027	·019	·016	·011	·006	·000	·010	·037	·045	·049
Sums	·096	·087	·065	·049	·034	·009	·005	·058	·154	·193	·191
Means	·024	·022	·016	·012	·008	·002	·001	·014	·038	·048	·048
Variation	·023	·021	·015	·011	·007	·001	·000	·013	·037	·047	·047

Diurnal Variation of the

March .....1847.....	.....	.....	.....	·021	·012	·005	·000	·020	·041	·047	·049
April	.....	.....	.....	·033	·013	·000	·000	·025	·048	·073	·073
May	.....	.....	.....	·034	·020	·012	·000	·027	·057	·071	·076
June	.....	.....	.....	·027	·017	·003	·000	·014	·039	·062	·044
Sums	.....	.....	.....	·115	·063	·020	·000	·086	·185	·253	·242
Means and Variation .	.....	.....	.....	·029	·015	·005	·000	·021	·046	·063	·061

TABLE C.

Sarawak in the Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·084	·089	·091	·081	·089	·087	·074	·083	·077	·064	·049	·045	·032	·052
·073	·068	·066	·064	·073	·087	·072	·093	·072	·058	·049	·045	·036	·045
·073	·074	·087	·086	·074	·071	·087	·099	·074	·065	·060	·048	·043	·049
·230	·231	·244	·231	·236	·245	·233	·275	·223	·187	·158	·138	·111	·146
·077	·077	·081	·077	·079	·082	·078	·092	·074	·062	·053	·046	·037	·049

Tension of Vapour at Padang in Sumatra.

·152	·160	·164	·166	·153	·150	·152	·130	·107	·084	·084	.....	.....	·100
·129	·158	·154	·159	·146	·140	·118	·103	·106	·086	·076	.....	.....	·088
·160	·162	·177	·159	·134	·124	·116	·107	·090	·064	·065	.....	.....	·087
·165	·181	·193	·171	·179	·178	·151	·116	·108	·098	·084	.....	.....	·101
·606	·661	·688	·655	·612	·592	·537	·456	·411	·332	·309	.....	.....	·376
·151	·165	·171	·168	·152	·147	·133	·113	·102	·082	·077	.....	.....	·093

Tension of Vapour at Singapore.

·033	·038	·051	·056	·048	·047	·038	·047	·054	·049	·050	.....	.....	·030
·023	·041	·047	·024	·040	·031	·026	·037	·046	·044	·040	.....	.....	·036
·056	·079	·098	·080	·088	·078	·064	·084	·100	·093	·090	.....	.....	·056
·028	·039	·049	·040	·044	·039	·032	·042	·050	·046	·045	.....	.....	·028
·027	·038	·048	·039	·043	·038	·031	·041	·049	·045	·044	.....	.....	·027

Tension of Vapour at Batavia. Winter.

·053	·068	·054	·061	·068	·055	·064	·060	·062	·054	·046	·047	·036	·038
·062	·055	·060	·055	·048	·037	·033	·036	·042	·041	·038	·041	·032	·029
·046	·043	·053	·051	·054	·051	·051	·039	·045	·049	·038	·046	·039	·034
·051	·045	·053	·050	·042	·037	·040	·041	·049	·040	·048	·047	·042	·035
·212	·211	·220	·217	·212	·180	·188	·176	·198	·184	·170	·181	·149	·136
·053	·053	·055	·054	·053	·045	·047	·044	·049	·046	·042	·045	·037	·034
·052	·052	·054	·053	·052	·044	·046	·043	·048	·045	·041	·044	·036	·033

Tension of Vapour at Batavia. Spring.

·052	·054	·054	·066	·065	·061	·049	·047	·040	·038	·020	.....	.....	·039
·075	·074	·069	·074	·065	·059	·055	·055	·041	·039	·022	.....	.....	·044
·084	·076	·083	·091	·085	·087	·081	·076	·083	·075	·069	.....	.....	·061
·041	·052	·055	·057	·056	·053	·058	·060	·051	·049	·044	.....	.....	·040
·252	·256	·261	·288	·271	·260	·243	·238	·215	·201	·155	.....	.....	·184
·063	·064	·065	·072	·068	·065	·061	·059	·054	·050	·049	.....	.....	·046

TABLE C.

Mean Degree of Humidity of the Air at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Moulmein	.....	.....	.....	90	91	89	89	84	72	65	57
Madras	.....	.....	.....	84	83	83	83	81	72	66	60
Nicobar	.....	.....	.....	94	93	93	92	93	88	83	77
Samboanga	.....	.....	.....	90	90	91	91	85	78	79	77
Pulo Penang	.....	.....	.....	91	91	93	91	91	89	84	80
Pulo Dinding	.....	.....	.....	90	89	90	90	92	81	77	63
Sarawak	97	98	98	98	98	98	99	99	97	93	88
Keemah	.....	.....	.....	93	93	93	92	92	79	77	73
Pulo Peesang	.....	.....	.....	.....	98	99	99	98	96	92	83
Singapore	.....	.....	.....	86	86	87	87	88	86	84	82
Carimon	.....	.....	.....	.....	.....	93	95	91	84	79	74
Padang	.....	.....	.....	94	93	93	93	92	85	79	74
Bencoolen	.....	.....	.....	100	100	100	100	98	89	86	80
Batavia, Winter	93	94	95	96	96	96	97	94	91	85	80
Batavia, Spring	.....	.....	.....	95	96	96	97	95	89	81	78
Cocos	.....	.....	.....	83	84	84	84	84	82	80	78

Mean Degree of Humidity of

June 1846	98	99	99	99	99	99	99	99	97	93	87
July	97	97	97	97	98	97	99	99	97	93	90
August	97	97	97	97	98	98	98	99	97	92	87
Means	97	98	98	98	98	98	99	99	97	93	88

Mean Degree of Humidity of

October 1847	.....	.....	.....	94	94	93	93	92	84	79	72
November	.....	.....	.....	94	94	94	94	91	84	78	74
December	.....	.....	.....	92	91	92	92	91	86	80	73
January 1848	.....	.....	.....	94	93	94	94	93	86	80	76
Means	.....	.....	.....	94	93	93	93	92	85	79	74

Mean Degree of Humidity of

November 1848	.....	.....	.....	87	87	87	88	88	88	86	84
December	.....	.....	.....	86	86	87	87	88	85	83	81
Means	.....	.....	.....	86	86	87	87	88	86	84	82

Mean Degree of Humidity

November 1846	93	94	94	95	95	95	97	93	88	82	76
December	93	94	95	96	96	96	96	94	89	83	77
January 1847	93	94	95	96	97	97	98	95	91	86	83
February	95	96	96	97	96	96	96	96	95	89	85
Means	93	94	95	96	96	96	97	94	91	85	80

Mean Degree of Humidity of

March 1847	.....	.....	.....	95	95	96	96	96	92	86	81
April	.....	.....	.....	96	96	96	97	96	91	85	79
May	.....	.....	.....	96	96	97	97	95	88	78	75
June	.....	.....	.....	95	96	96	97	94	87	77	70
Means	.....	.....	.....	95	96	96	97	95	89	81	78

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Table C.

various stations in the Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
51	50	47	43	48	50	55	66	74	81	82	.....	.....	66
55	52	51	52	56	61	65	71	78	81	82	.....	.....	68
74	74	74	76	77	79	80	86	88	90	91	.....	.....	84
77	78	73	76	74	77	79	84	84	86	87	.....	.....	81
76	76	76	77	76	80	82	85	88	88	89	.....	.....	84
58	58	59	63	70	72	79	84	86	84	88	.....	.....	76
83	79	78	77	80	82	85	92	95	96	96	97	97	91
72	71	74	78	79	80	85	88	90	90	91	.....	.....	83
75	70	71	79	85	87	93	94	96	94	96	.....	.....	88
81	81	82	82	83	84	84	85	87	87	88	.....	.....	85
69	69	68	68	71	74	78	86	87	87	.....	.....	.....	79
71	69	68	70	73	78	82	88	91	92	94	.....	.....	83
79	79	81	86	86	86	90	95	95	95	97	.....	.....	88
76	75	75	75	76	77	81	85	89	90	91	93	93	87
74	71	71	74	74	75	78	84	86	88	89	.....	.....	83
76	76	77	79	80	81	82	83	83	82	83	.....	.....	81

the Air at Sarawak, Borneo.

83	79	78	78	81	83	86	93	95	96	96	97	97	92
84	79	79	77	82	83	84	92	95	96	96	97	96	91
82	78	76	75	76	81	86	92	95	96	97	96	97	91
83	79	78	77	80	82	85	92	95	96	96	97	97	91

the Air at Padang in Sumatra.

71	71	72	72	75	80	86	89	91	93	94	.....	.....	83
70	69	69	72	75	79	82	87	91	92	94	.....	.....	83
70	65	66	67	70	76	81	88	90	90	94	.....	.....	81
73	71	67	68	73	77	81	88	91	95	96	.....	.....	83
71	69	68	70	73	78	82	88	91	92	94	.....	.....	83

the Air at Singapore.

83	82	84	84	85	85	85	87	88	88	89	.....	.....	86
80	80	81	81	82	82	83	84	86	86	86	.....	.....	84
81	81	82	82	83	84	84	85	87	87	88	.....	.....	85

of the Air at Batavia in Java. Winter.

73	72	72	72	75	77	82	88	90	91	92	93	93	86
75	76	76	76	75	77	82	86	90	92	93	94	94	87
79	76	74	74	77	75	78	81	85	87	87	91	92	86
81	78	78	77	78	80	84	87	90	91	93	94	95	88
76	75	75	75	76	77	81	85	89	90	91	93	93	87

the Air at Batavia in Java. Spring.

79	76	75	76	76	77	79	85	87	89	90	.....	.....	85
77	74	74	76	76	77	80	84	85	87	88	.....	.....	84
72	69	71	74	74	76	79	84	89	90	91	.....	.....	83
67	66	66	67	68	70	75	82	83	86	87	.....	.....	80
74	71	71	74	74	75	78	84	86	88	89	.....	.....	83

TABLE C.

Observatory at Moulmein—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Noon.
Dry Thermometer.										
Mean of 7 days.....	77·1	76·8	76·6	76·7	79·5	87·1	90·8	95·4	98·5	100·9
Diurnal variation ...	0·5	0·2	0·0	0·1	2·9	10·5	14·2	18·8	21·9	24·3
Wet Thermometer.										
Mean of 7 days.....	74·9	74·8	74·2	74·3	76·1	79·7	80·9	82·1	82·6	83·3
Diurnal variation ...	0·7	0·6	0·0	0·1	1·9	5·5	6·7	7·9	8·4	9·1
Tension of vapour...	·826	·825	·803	·805	·846	·908	·919	·924	·912	·917

Observatory at Madras.—Hourly observations made

Dry Thermometer.										
Mean of 32 days ...	78·9	78·6	78·1	77·8	79·2	82·3	85·5	88·2	90·5	92·3
Diurnal variation ...	1·1	0·8	0·3	0·0	1·4	4·5	7·7	10·4	12·7	14·5
Wet Thermometer.										
Mean of 32 days ...	75·0	74·6	74·1	73·7	74·6	75·3	76·3	76·8	77·2	77·7
Diurnal variation ...	1·3	0·9	0·4	0·0	0·9	1·6	1·9	3·1	3·5	4·0
Tension of vapour ...	·810	·797	·783	·771	·790	·782	·785	·776	·766	·767

Observatory at Car Nicobar.—Hourly observations

Dry Thermometer.										
Mean of 5 days.....	73·0	73·6	73·8	73·9	75·0	79·6	82·0	85·8	86·5	86·7
Diurnal variation ...	0·0	0·6	0·8	0·9	2·0	6·6	9·0	12·8	13·5	13·7
Wet Thermometer.										
Mean of 5 days.....	71·7	72·2	72·2	72·2	73·4	76·8	77·8	79·9	79·7	79·9
Diurnal variation ...	0·0	0·5	0·5	0·5	1·7	5·1	6·1	8·2	8·0	8·2
Tension of vapour ...	·750	·762	·760	·759	·791	·873	·885	·935	·919	·925

Observatory at Sambooanga.—Hourly observations

Dry Thermometer.										
Mean of 6 days.....	74·7	74·6	74·8	74·5	79·2	84·1	85·3	85·7	84·5	86·9
Diurnal variation ...	0·2	0·1	0·3	0·0	4·7	9·6	10·8	11·2	10·0	12·4
Wet Thermometer.										
Mean of 6 days.....	72·5	72·5	72·9	72·5	75·6	78·6	80·0	79·7	78·7	80·1
Diurnal variation ...	0·0	0·0	0·4	0·0	3·1	6·1	7·5	7·2	6·2	7·6
Tension of vapour...	·760	·761	·774	·762	·829	·898	·945	·928	·897	·931

Observatory at Penang.—Hourly observations

Dry Thermometer.										
Mean of 5 days.....	76·4	75·9	74·9	75·1	76·0	78·2	82·4	86·0	88·0	86·9
Diurnal variation ...	1·5	1·0	0·0	0·2	1·1	3·3	7·5	11·1	13·1	12·0
Wet Thermometer.										
Mean of 5 days.....	74·3	74·0	73·3	73·2	74·0	75·6	78·5	80·8	81·6	80·8
Diurnal variation ...	1·3	1·0	0·3	0·2	0·0	2·6	5·5	7·8	8·6	7·8
Tension of vapour...	·809	·804	·788	·782	·803	·840	·913	·970	·984	·959

TABLE C.

made during the Month of April, 1849.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Tension of Vapour.
Dry Thermometer.												
	100·3	100·6	97·0	95·4	92·3	86·4	83·2	81·3	80·6	1676·5	88·3	
	23·7	24·0	20·4	18·8	15·7	9·8	6·6	4·7	4·0			
Wet Thermometer.												
	82·6	81·3	80·3	79·7	78·8	77·2	76·7	76·5	76·2	1492·2	78·5	·846
	8·4	7·1	6·1	5·5	4·6	3·0	2·5	2·3	2·0			
	·888	·827	·824	·818	·813	·813	·828	·842	·837			

during the Months of August and September, 1849.

Dry Thermometer.												
	93·3	92·9	91·5	90·0	87·4	85·0	83·2	82·3	81·7	1618·7	85·2	
	15·5	15·1	13·7	12·2	9·6	7·2	5·4	4·5	3·9			
Wet Thermometer.												
	78·1	78·2	78·5	78·2	77·9	77·4	77·6	77·5	77·3	1456·0	76·6	·801
	4·4	4·5	4·8	4·5	4·2	3·7	3·9	3·8	3·6			
	·772	·781	·810	·841	·830	·837	·866	·871	·870	.....	·801	

made during the Month of February, 1849.

Dry Thermometer.												
	87·6	85·5	85·2	84·6	83·3	80·4	78·5	77·6	76·4	1529·0	80·5	
	14·6	12·5	12·2	11·6	10·3	7·4	5·5	4·6	3·4			
Wet Thermometer.												
	80·8	79·2	79·3	79·1	78·4	77·0	75·7	75·3	74·3	1454·9	76·6	·853
	9·1	7·5	7·6	7·4	6·7	5·3	4·0	3·6	2·6			
	·952	·909	·917	·916	·898	·872	·841	·835	·809	.....	·855	

made during the Month of May, 1848.

Dry Thermometer.												
	87·8	88·5	88·0	86·7	84·6	82·3	81·6	80·0	79·1	1562·9	82·2	
	13·3	14·0	13·5	12·2	10·1	7·8	7·1	5·5	4·6			
Wet Thermometer.												
	80·5	81·6	81·1	80·8	79·3	78·3	77·6	76·6	76·1	1475·0	77·6	·877
	8·0	9·1	8·6	8·3	6·8	5·8	5·1	4·1	3·6			
	·937	·979	·961	·962	·924	·906	·884	·860	·850	.....	·877	

made during the Month of January, 1849.

Dry Thermometer.												
	86·3	85·4	85·6	84·8	82·8	80·7	79·6	79·1	78·3	1542·4	81·2	
	11·4	10·5	10·7	9·9	7·9	5·8	4·7	4·2	3·4			
Wet Thermometer.												
	80·0	79·5	79·3	79·6	78·3	77·2	76·8	76·3	75·7	1468·8	77·3	·876
	7·0	6·5	6·3	6·6	5·3	4·2	3·8	3·3	2·7			
	·933	·923	·913	·934	·900	·877	·873	·858	·843	.....	·876	

TABLE C.

Observatory at Pulo Dinding.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Dry Thermometer.													
Mean of 3 days ...	.....	.....	.....	75·3	74·9	74·2	73·9	74·4	79·7	85·0	92·3	96·1	94·4
Diurnal variation ...	.....	.....	.....	1·4	1·0	0·3	0·0	0·5	5·8	11·1	18·4	22·2	20·5
Wet Thermometer.													
Mean of 3 days ...	.....	.....	.....	73·2	72·5	72·1	71·7	72·7	75·3	79·0	81·7	83·2	81·7
Diurnal variation ...	.....	.....	.....	1·5	0·8	0·4	0·0	1·0	3·6	7·3	10·0	11·5	10·0
Tension of vapour ...	.....	.....	.....	·780	·758	·751	·740	·771	·811	·905	·940	·966	·916

Observatory at Sarawak.—Hourly observations

Dry Thermometer.													
Mean of 26 days ...	77·0	76·6	76·3	76·1	75·9	75·9	75·5	76·0	77·5	79·8	82·2	84·0	85·4
Diurnal variation ...	1·5	1·1	0·8	0·6	0·4	0·4	0·0	0·5	2·0	4·3	6·7	8·5	9·9
Wet Thermometer.													
Mean of 26 days ...	76·5	76·3	76·1	75·9	75·7	75·6	75·3	75·7	76·8	78·2	79·1	79·6	80·1
Diurnal variation ...	1·2	1·0	0·8	0·6	0·4	0·3	0·0	0·4	1·5	2·9	3·8	4·3	4·8
Tension of vapour ...	·890	·887	·882	·877	·871	·867	·859	·869	·897	·930	·936	·943	·948

Observatory at Sarawak.—Hourly observations

Dry Thermometer.													
Mean of 27 days ...	76·6	76·3	76·0	75·7	75·5	75·4	74·8	75·1	76·4	78·6	80·5	82·4	83·9
Diurnal variation ...	1·8	1·5	1·2	0·9	0·7	0·6	0·0	0·3	1·6	3·8	5·7	7·6	9·1
Wet Thermometer.													
Mean of 27 days ...	76·0	75·8	75·5	75·2	75·1	74·9	74·6	74·9	75·8	77·2	77·9	78·5	78·8
Diurnal variation ...	1·4	1·2	0·9	0·6	0·5	0·3	0·0	0·3	1·2	2·6	3·3	3·9	4·2
Tension of vapour ...	·875	·870	·861	·853	·851	·846	·840	·849	·869	·901	·920	·913	·908

Observatory at Sarawak.—Hourly observations

Dry Thermometer.													
Mean of 19 days ...	76·2	75·9	75·6	75·4	75·2	74·9	74·6	74·8	76·1	78·6	80·7	82·6	84·3
Diurnal variation ...	1·6	1·3	1·0	0·8	0·6	0·3	0·0	0·2	1·5	4·0	6·1	8·0	9·7
Wet Thermometer.													
Mean of 19 days ...	75·5	75·3	75·0	74·8	74·7	74·4	74·2	74·5	75·4	76·7	77·6	78·2	78·7
Diurnal variation ...	1·3	1·1	0·8	0·6	0·5	0·2	0·0	0·3	1·2	2·5	3·4	4·0	4·5
Tension of vapour ...	·859	·854	·847	·841	·839	·830	·825	·836	·856	·880	·894	·898	·899

Observatory at Keemah.—Hourly observations

Dry Thermometer.													
Mean of 10 days ...	.....	.....	.....	74·0	73·7	73·4	73·0	75·7	82·4	85·3	88·6	90·1	91·6
Diurnal variation ...	.....	.....	.....	1·0	0·7	0·4	0·0	2·7	9·4	12·3	15·6	17·1	18·6
Wet Thermometer.													
Mean of 10 days ...	.....	.....	.....	72·4	72·2	71·9	71·3	73·9	77·3	79·4	81·2	82·3	83·4
Diurnal variation ...	.....	.....	.....	1·1	0·9	0·6	0·0	2·6	6·0	8·1	9·9	11·0	12·1
Tension of vapour ...	.....	.....	.....	·765	·761	·753	·736	·802	·862	·920	·959	·993	1·027

TABLE C.

made during the Month of January, 1849.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Tension of Vapour.
Dry Thermometer.														
	95·7	92·4	90·3	87·0	83·0	79·3	78·2	77·9	77·2	.....	.....	1581·2	83·2	
	21·8	18·5	16·4	13·1	9·1	5·4	4·3	4·0	3·3	.....	.....			
Wet Thermometer.														
	83·1	81·5	82·3	79·4	77·8	75·5	74·9	74·1	74·4	.....	.....	1466·1	77·1	·844
	11·4	9·8	10·6	7·7	6·1	3·8	3·2	2·4	2·7	.....	.....			
	·967	·930	·996	·901	·876	·824	·813	·785	·804	.....	.....	.....	·844	

made during the Month of June, 1846.

Dry Thermometer.														
	85·9	85·7	84·7	83·8	82·5	80·2	79·2	78·5	78·0	77·6	77·3	1911·6	79·6	
	10·4	10·2	9·2	8·3	7·0	4·7	3·7	3·0	2·5	2·1	1·8			
Wet Thermometer.														
	80·3	80·0	79·9	79·6	79·0	78·6	78·2	77·7	77·2	77·0	76·6	1865·0	77·7	·911
	5·0	4·7	4·6	4·3	3·7	3·3	2·9	2·4	1·9	1·7	1·3			
	·950	·940	·948	·946	·933	·942	·936	·923	·908	·904	·891	.....	·911	

made during the Month of July, 1846.

Dry Thermometer.														
	84·1	84·6	83·5	83·1	82·1	80·2	78·4	77·8	77·5	77·1	76·8	1892·4	78·9	
	9·3	9·8	8·7	8·3	7·3	5·4	3·6	3·0	2·7	2·3	2·0			
Wet Thermometer.														
	78·8	78·9	78·8	79·0	78·4	78·4	77·4	76·9	76·6	76·4	76·1	1845·9	76·9	·885
	4·2	4·3	4·2	4·4	3·8	3·8	2·8	2·3	2·0	1·8	1·5			
	·906	·904	·913	·927	·912	·933	·912	·898	·889	·885	·876	.....	·885	

made during the Month of August, 1846.

Dry Thermometer.														
	85·6	85·7	85·1	82·8	81·7	79·9	78·1	77·4	77·1	76·8	76·5	1891·6	78·8	
	11·0	11·1	10·5	9·2	7·1	5·3	3·5	2·8	2·5	2·2	1·9			
Wet Thermometer.														
	79·3	79·3	78·9	78·2	78·3	78·1	77·0	76·6	76·4	76·0	75·8	1838·9	76·6	·874
	5·1	5·1	4·7	4·0	4·1	3·9	2·8	2·4	2·2	1·8	1·6			
	·912	·911	·899	·896	·912	·924	·899	·890	·885	·873	·868	.....	·874	

made during the Month of June, 1848.

Dry Thermometer.														
	87·1	85·6	84·6	83·7	81·5	79·8	78·6	77·7	77·0	.....	.....	1543·4	81·1	
	14·1	12·6	11·6	10·7	8·5	6·8	5·6	4·7	4·0	.....	.....			
Wet Thermometer.														
	80·1	80·0	79·2	78·5	77·9	77·0	76·3	75·5	75·0	.....	.....	1464·8	77·0	·865
	8·8	8·7	7·9	7·2	6·6	5·7	5·0	4·2	3·7	.....	.....			
	·929	·941	·920	·898	·897	·879	·864	·842	·832	.....	.....	.....	·865	

Table C.

Observatory at Pulo Peesang.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Dry Thermometer.										
Mean of 5 days	.....	75·9	75·1	75·3	76·1	77·1	80·1	84·3	87·1	88·6
Diurnal variation	.....	0·8	0·0	0·2	1·0	2·0	5·0	9·2	12·0	13·5
Wet Thermometer.										
Mean of 5 days	.....	75·4	74·9	75·0	75·7	76·2	77·9	79·9	80·6	80·5
Diurnal variation	.....	0·5	0·0	0·1	0·8	1·3	3·0	5·0	5·7	5·6
Tension of vapour	.....	·858	·849	·851	·869	·877	·913	·952	·949	·928

Observatory at Singapore.—Hourly observations

Dry Thermometer.										
Mean of 16 days	79·4	79·2	79·1	78·8	78·3	78·9	79·9	80·7	81·5	81·8
Diurnal variation	1·1	0·9	0·8	0·5	0·0	0·6	1·6	2·4	3·2	3·5
Wet Thermometer.										
Mean of 16 days	76·5	76·3	76·2	76·0	75·6	76·0	76·5	76·9	77·3	77·5
Diurnal variation	0·9	0·7	0·6	0·4	0·0	0·4	0·9	1·3	1·7	1·9
Tension of vapour	·863	·857	·854	·850	·839	·849	·857	·865	·872	·877

Observatory at Singapore.—Hourly observations

Dry Thermometer.										
Mean of 14 days	79·2	79·0	78·7	77·9	77·7	78·8	80·2	80·8	81·4	82·0
Diurnal variation	1·5	1·3	1·0	0·2	0·0	1·1	2·5	3·1	3·7	4·3
Wet Thermometer.										
Mean of 14 days	75·9	75·8	75·7	74·9	74·9	75·3	76·0	76·2	76·5	77·1
Diurnal variation	1·0	0·9	0·8	0·0	0·0	0·4	1·1	1·3	1·6	2·2
Tension of vapour	·841	·839	·839	·817	·819	·822	·835	·835	·840	·858

Observatory at Carimon Island.—Hourly observations

Dry Thermometer.										
Mean of 6 days	.....	.....	76·9	76·3	78·7	81·8	84·3	86·1	89·1	88·5
Diurnal variation	.....	.....	0·6	0·0	2·4	5·5	8·0	9·8	12·8	12·2
Wet Thermometer.										
Mean of 6 days	.....	.....	75·3	75·2	76·6	77·9	78·9	79·3	80·5	80·0
Diurnal variation	.....	.....	0·1	0·0	1·4	2·7	3·7	4·1	5·3	4·8
Tension of vapour	.....	.....	·843	·847	·875	·894	·908	·907	·922	·908

Observatory at Padang.—Hourly observations

Dry Thermometer.										
Mean of 13 days	72·9	72·7	72·5	72·4	74·4	78·9	82·9	85·0	86·4	87·0
Diurnal variation	0·5	0·3	0·1	0·0	2·0	6·5	10·5	12·6	14·0	14·6
Wet Thermometer.										
Mean of 13 days	71·6	71·4	71·1	70·9	72·6	75·1	77·6	77·8	78·8	79·1
Diurnal variation	0·7	0·5	0·2	0·0	1·7	4·2	6·7	6·9	7·9	8·2
Tension of vapour	·747	·743	·734	·728	·768	·813	·869	·853	·880	·888

TABLE C.

made during the Month of January, 1846.

1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Tension of Vapour.
Dry Thermometer.											
88·8	84·8	82·4	81·8	79·3	78·2	78·0	78·1	77·2	1448·2	80·8	
13·7	9·7	7·3	6·7	4·2	3·1	2·9	3·0	2·1			
Wet Thermometer.											
80·9	79·4	78·5	78·8	77·7	76·9	77·0	76·8	76·4	1398·5	77·9	·905
6·0	4·5	3·6	3·9	2·8	2·0	2·1	1·9	1·5			
·942	·926	·913	·932	·914	·893	·900	·891	·884	.....	·905	

made during the Month of November, 1848.

Dry Thermometer.											
81·8	81·7	81·3	81·0	80·7	80·6	80·4	80·1	79·7	1524·9	80·3	
3·5	3·4	3·0	2·7	2·4	2·3	2·1	1·8	1·4			
Wet Thermometer.											
77·8	77·9	77·6	77·5	77·2	77·4	77·5	77·3	77·2	1462·2	76·9	·869
2·2	2·3	3·0	1·9	1·6	1·8	1·9	1·7	1·6			
·890	·895	·887	·886	·877	·886	·893	·888	·889	.....	·869	

made during the Month of December, 1848.

Dry Thermometer.											
81·9	81·2	81·2	81·1	80·5	80·2	80·1	79·9	79·6	1522·5	80·1	
4·2	3·5	3·5	3·4	2·8	2·5	2·4	2·2	1·9			
Wet Thermometer.											
77·2	76·7	76·9	76·6	76·3	76·5	76·7	76·6	76·4	1448·2	76·2	·843
2·3	1·8	2·0	1·7	1·4	1·6	1·8	1·7	1·5			
·864	·841	·857	·848	·843	·854	·863	·861	·857	.....	·843	

made during the Month of January, 1846.

Dry Thermometer.											
89·3	89·6	87·4	86·3	84·3	81·0	80·0	79·1	.....	1338·7	83·8	
13·0	13·3	11·1	10·0	8·0	4·7	3·7	2·8				
Wet Thermometer.											
80·5	80·9	79·7	79·5	78·7	77·7	76·9	76·2	.....	1253·8	78·4	·893
5·3	5·7	4·5	4·3	3·5	2·5	1·7	1·0				
·920	·933	·909	·913	·899	·894	·873	·854	.....	.....	·893	

made during the Month of October, 1847.

Dry Thermometer.											
86·7	86·5	84·8	82·8	80·5	78·7	77·3	75·8	75·2	1513·4	79·7	
14·3	14·1	12·4	10·4	8·1	6·3	4·9	3·4	2·8			
Wet Thermometer.											
79·1	79·1	78·4	77·8	77·2	76·1	75·2	74·2	74·0	1437·1	75·7	·828
8·2	8·2	7·5	6·9	6·3	5·2	4·3	3·3	3·1			
·892	·894	·881	·878	·880	·858	·835	·812	·812	.....	·828	

Table C.

Observatory at Padang.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Dry Thermometer.													
Mean of 26 days ...	.....	.....	.....	73·4	73·1	72·9	72·9	74·8	79·4	83·0	85·0	86·7	88·2
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·0	0·0	1·9	6·5	10·1	12·1	13·8	15·3
Wet Thermometer.													
Mean of 26 days ...	.....	.....	.....	72·0	71·8	71·7	71·6	72·9	75·6	77·5	78·1	78·8	79·8
Diurnal variation ...	.....	.....	.....	0·4	0·2	0·1	0·0	1·3	4·0	5·9	6·5	7·2	8·2
Tension of vapour...	.....	.....	.....	·757	·753	·751	·747	·775	·827	·864	·867	·876	·905

Observatory at Padang.—Hourly observations

Dry Thermometer.													
Mean of 26 days ...	.....	.....	.....	73·7	73·4	73·1	73·1	74·3	78·6	83·0	85·8	87·5	89·9
Diurnal variation ...	.....	.....	.....	0·6	0·3	0·0	0·0	1·2	5·5	9·9	12·7	14·4	16·8
Wet Thermometer.													
Mean of 26 days ...	.....	.....	.....	71·9	71·6	71·4	71·4	72·4	75·3	77·5	78·7	79·5	80·2
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·0	0·0	1·0	3·9	6·1	7·3	8·1	8·8
Tension of vapour...	.....	.....	.....	·749	·741	·739	·739	·761	·823	·888	·882	·899	·901

Observatory at Padang.—Hourly observations

Dry Thermometer.													
Mean of 13 days ...	.....	.....	.....	73·8	73·5	73·3	73·3	74·2	78·5	82·9	84·9	87·2	88·7
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·0	0·0	0·9	5·2	9·6	11·6	13·9	15·4
Wet Thermometer.													
Mean of 13 days ...	.....	.....	.....	72·4	72·1	71·9	72·0	72·6	75·2	77·9	78·6	79·9	80·7
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·0	0·1	0·7	3·3	6·0	6·7	8·0	8·8
Tension of vapour...	.....	.....	.....	·767	·759	·754	·758	·770	·821	·881	·888	·919	·935

Observatory at Poolo Bay.—Hourly observations

Dry Thermometer.													
Mean of 5 days ...	.....	.....	.....	73·4	73·2	72·0	73·0	76·0	79·1	81·7	84·3	84·9	85·6
Diurnal variation ...	.....	.....	.....	1·4	1·2	0·0	1·0	4·0	7·1	9·7	12·3	12·9	13·6
Wet Thermometer.													
Mean of 5 days ...	.....	.....	.....	73·8	73·5	73·3	73·3	75·5	77·1	78·3	79·2	79·5	80·1
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·0	0·0	2·2	3·8	5·0	5·9	6·2	6·8
Tension of vapour ...	.....	.....	.....	·820	·812	·806	·806	·861	·891	·913	·923	·929	·946

Observatory at Batavia.—Hourly observations

Dry Thermometer.													
Mean of 19 days ...	77·0	76·6	76·3	75·9	75·7	75·5	75·1	77·0	79·5	82·2	84·3	85·9	86·7
Diurnal variation ...	1·9	1·5	1·2	0·8	0·6	0·4	0·0	1·9	4·4	7·1	9·2	10·6	11·6
Wet Thermometer.													
Mean of 19 days ...	75·5	75·3	75·0	74·8	74·7	74·5	74·4	75·5	76·7	77·7	78·0	78·7	79·2
Diurnal variation ...	1·1	0·9	0·6	0·4	0·3	0·1	0·0	1·1	2·3	3·3	3·6	4·3	4·8
Tension of vapour...	·850	·846	·839	·836	·834	·828	·828	·850	·870	·881	·870	·881	·896

TABLE C.

made during the Month of November, 1847.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Tension of Vapour.
Dry Thermometer.													
88·1	86·9	85·2	83·6	81·4	79·1	77·8	76·8	75·9	.....	.....	1524·2	80·2	
15·2	14·0	12·3	10·7	8·5	6·2	4·9	3·9	3·0					
Wet Thermometer.													
79·7	79·5	78·8	78·2	77·1	76·1	75·8	75·0	74·5	.....	.....	1444·5	76·0	·835
8·1	7·9	7·2	6·6	5·5	4·5	4·2	3·4	2·9					
·901	·906	·893	·887	·865	·850	·853	·833	·823	.....	.....	.....	·835	

made during the Month of December, 1847.

Dry Thermometer.													
90·0	89·0	87·0	83·8	81·6	78·8	77·2	76·3	75·2	.....	.....	1531·3	80·6	
16·9	15·9	13·9	10·7	8·5	5·7	4·1	3·2	2·1					
Wet Thermometer.													
80·6	79·9	78·8	77·7	76·9	75·9	75·0	74·1	73·8	.....	.....	1442·6	75·9	·826
9·2	8·5	7·4	6·3	5·5	4·5	3·6	2·7	2·4					
·916	·898	·873	·863	·855	·846	·829	·803	·804	.....	.....	.....	·826	

made during the Month of January, 1848.

Dry Thermometer.													
90·9	89·6	87·8	85·8	83·2	79·5	78·0	76·5	75·7	.....	.....	1537·3	80·9	
17·6	16·3	14·5	12·5	9·9	6·2	4·7	3·2	2·4	.....	.....			
Wet Thermometer.													
81·5	80·7	80·4	79·8	78·3	76·7	76·1	75·4	74·8	.....	.....	1457·0	76·7	·855
9·6	8·8	8·5	7·9	6·4	4·8	4·2	3·5	2·9	.....	.....			
·947	·925	·933	·932	·905	·870	·862	·852	·838	.....	.....	.....	·855	

made during the Months of August and September, 1847.

Dry Thermometer.													
85·0	83·3	82·0	82·5	80·7	78·2	77·1	76·3	75·6	.....	.....	1504·9	79·3	
13·0	11·3	10·0	10·5	8·7	6·2	5·1	4·3	3·6	.....	.....			
Wet Thermometer.													
80·2	79·8	78·7	79·0	78·4	77·0	75·9	75·2	74·9	.....	.....	1462·7	77·0	·865
6·9	6·5	5·4	5·7	5·1	3·7	2·6	1·9	1·6	.....	.....			
·957	·960	·925	·933	·928	·897	·865	·847	·843	.....	.....	.....	·865	

made during the Month of November, 1846.

Dry Thermometer.													
86·2	86·4	85·3	84·3	82·4	80·1	79·6	78·9	78·4	78·0	77·6	1924·9	80·2	
11·1	11·3	10·2	9·2	7·3	5·0	4·5	3·8	1·3	2·9	2·5			
Wet Thermometer.													
78·8	79·0	78·9	78·3	78·0	77·3	77·2	76·8	76·5	76·4	76.0	1843·2	76·8	·866
4·4	4·6	4·5	3·9	3·6	2·9	2·8	2·4	2·1	2·0	1·6			
·882	·889	·896	·883	·892	·888	·890	·882	·874	·875	·864	.....	·866	

TABLE C.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Dry Thermometer.													
Mean of 26 days ...	77·0	76·6	76·3	76·0	75·6	75·4	75·3	76·6	79·2	82·0	84·2	85·3	84·8
Diurnal variation ...	1·7	1·3	1·0	0·7	0·3	0·1	0·0	1·3	3·9	6·7	8·9	10·0	9·5
Wet Thermometer.													
Mean of 26 days ...	75·5	75·3	75·2	75·0	74·8	74·6	74·5	75·3	76·7	77·8	78·3	78·8	78·5
Diurnal variation ...	1·0	0·8	0·7	0·5	0·3	0·1	0·0	0·8	2·2	3·3	3·8	4·3	4·0
Tension of vapour ...	·850	·846	·846	·843	·839	·833	·830	·846	·873	·887	·884	·892	·885

Observatory at Batavia.—Hourly observations

Dry Thermometer.													
Mean of 25 days ...	77·1	76·6	76·0	75·5	75·1	74·8	74·6	75·7	77·9	79·8	81·3	82·6	83·8
Diurnal variation ...	2·5	2·0	1·4	0·9	0·5	0·2	0·0	1·1	3·3	5·2	6·7	8·0	9·2
Wet Thermometer.													
Mean of 25 days ...	75·5	75·3	74·9	74·6	74·4	74·1	74·0	74·6	75·8	76·5	77·1	77·4	77·7
Diurnal variation ...	1·5	1·3	0·9	0·6	0·4	0·1	0·0	0·6	1·8	2·5	3·1	3·4	3·7
Tension of vapour ...	·849	·846	·839	·832	·828	·820	·825	·830	·852	·858	·866	·864	·863

Observatory at Batavia.—Hourly observations

Dry Thermometer.													
Mean of 24 days ...	76·9	76·7	76·3	76·1	76·0	75·8	75·6	76·1	77·5	79·7	81·2	82·6	83·8
Diurnal variation ...	1·3	1·1	0·7	0·5	0·4	0·2	0·0	0·5	1·9	4·1	5·6	7·0	8·2
Wet Thermometer.													
Mean of 24 days ...	75·8	75·8	75·5	75·4	75·2	75·0	74·8	75·2	76·3	77·1	77·6	78·0	78·2
Diurnal variation ...	1·0	1·0	0·7	0·6	0·4	0·2	0·0	0·4	1·5	2·3	2·8	3·2	3·4
Tension of vapour ...	·864	·866	·858	·855	·850	·845	·839	·849	·876	·884	·888	·890	·884

Observatory at Batavia.—Hourly observations

Dry Thermometer.													
Mean of 27 days ...	.....	.....	.....	77·3	76·8	76·3	76·1	76·8	78·8	81·2	83·0	84·2	85·1
Diurnal variation ...	.....	.....	.....	1·2	0·7	0·2	0·0	0·7	2·7	5·1	6·9	8·1	9·0
Wet Thermometer.													
Means of 27 days ...	.....	.....	.....	76·1	75·7	75·4	75·2	75·9	77·0	77·8	78·3	78·7	79·0
Diurnal variation ...	.....	.....	.....	0·9	0·5	0·2	0·0	0·7	1·8	2·6	3·1	3·5	3·8
Tension of vapour ...	.....	.....	.....	·870	·861	·854	·849	·869	·890	·896	·898	·901	·903

Observatory at Batavia.—Hourly observations

Dry Thermometer.													
Mean of 26 days ...	.....	.....	.....	76·7	76·0	75·4	75·0	76·3	78·9	81·9	84·1	85·2	86·1
Diurnal variation ...	.....	.....	.....	1·7	1·0	0·4	0·0	1·3	3·9	6·9	9·1	10·2	11·1
Wet Thermometer.													
Mean of 26 days ...	.....	.....	.....	75·8	75·1	74·6	74·5	75·5	76·8	78·2	78·8	79·1	79·3
Diurnal variation ...	.....	.....	.....	1·3	0·6	0·1	0·0	1·0	2·3	3·7	4·3	4·6	4·8
Tension of vapour ...	.....	.....	.....	·866	·846	·833	·833	·858	·881	·906	·906	·908	·907

Table C.

made during the Month of December, 1846.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.	Tension of Vapour.
Dry Thermometer.	84·8	84·8	84·7	83·4	81·6	79·9	79·0	78·3	77·9	77·6	77·0	1913·3	79·7	
	9·5	9·5	9·4	8·1	6·3	4·6	3·7	3·0	2·6	2·3	1·7			
Wet Thermometer.	78·6	78·5	78·3	77·7	77·1	76·7	76·6	76·4	76·2	76·2	75·8	1838·4	76·5	·859
	4·1	4·0	3·8	3·2	2·6	2·2	2·1	1·9	1·7	1·7	1·3			
	·890	·885	·878	·867	·863	·866	·872	·871	·868	·871	·862	·859		

made during the Month of January, 1847.

Dry Thermometer.	84·8	85·0	85·1	84·6	83·4	81·6	80·3	79·6	79·1	78·4	77·8	1910·5	79·8	
	10·2	10·4	10·5	10·0	8·8	7·0	5·7	5·0	4·5	+3·8	3·2			
Wet Thermometer.	78·2	78·2	78·3	78·1	77·8	77·0	76·8	76·7	76·5	76·3	76·0	1831·8	76·4	
	4·2	4·2	4·3	4·1	3·8	3·0	2·8	2·7	2·5	2·3	2·0			
	·73	·871	·874	·871	·871	·859	·865	·869	·858	·866	·859	.....	·854	

made during the Month of February, 1847.

Dry Thermometer.	84·2	84·5	83·7	82·6	81·3	80·1	79·4	78·7	78·4	78·1	77·5	1902·8	79·5	
	8·6	8·9	8·1	7·0	5·7	4·5	3·8	3·1	2·8	2·5	1·9			
Wet Thermometer.	78·5	78·5	78·1	77·7	77·4	77·1	77·1	76·7	76·8	76·7	76·4	1840·9	76·8	·874
	3·7	3·7	3·3	2·9	2·6	2·3	2·3	1·9	2·0	1·9	1·6			
	·892	·889	·881	·876	·879	·880	·888	·879	·887	·886	·881	.....	·874	

made during the Month of March, 1847.

Dry Thermometer.	85·7	85·7	85·8	85·1	83·7	81·6	80·7	79·8	78·9	.....	.....	1542·6	81·2	
	9·6	9·6	9·7	9·0	7·6	5·5	4·6	3·7	2·8	.....	.....			
Wet Thermometer.	79·1	79·4	79·4	79·1	78·5	77·9	77·5	77·2	76·5	.....	.....	1473·7	77·6	·888
	3·9	4·2	4·2	3·9	3·3	2·7	2·3	2·0	1·3	.....	.....			
	·903	·915	·914	·910	·898	·896	·889	·887	·869	.....	.....	.....	·888	

made during the Month of April, 1847.

Dry Thermometer.	86·1	85·4	85·1	84·6	83·1	81·6	80·6	79·7	79·0	.....	.....	1540·8	81·1	
	11·1	10·4	10·1	9·6	8·1	6·6	5·6	4·7	4·0	.....	.....			
Wet Thermometer.	79·2	79·1	78·9	78·6	78·1	77·6	77·1	76·8	76·2	.....	.....	1469·3	77·3	·877
	4·7	4·6	4·4	4·1	3·6	3·1	2·6	2·3	1·7	.....	.....			
	·902	·907	·898	·892	·888	·883	·874	·872	·855	.....	.....		·877	

TABLE C.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Dry Thermometer.										
Mean of 26 days ...	75·5	75·0	74·4	74·0	75·4	79·0	83·2	84·7	86·2	87·3
Diurnal variation ...	1·5	1·0	0·4	0·0	1·4	5·0	9·2	10·7	12·2	13·3
Wet Thermometer.										
Mean of 26 days ...	74·6	74·1	73·7	73·3	74·4	76·2	77·7	78·2	78·8	78·9
Diurnal variation ...	1·3	0·8	0·4	0·0	1·1	2·9	4·4	4·9	5·5	5·6
Tension of vapour ...	·832	·818	·810	·798	·825	·855	·869	·874	·882	.874

Observatory at Batavia.—Hourly observations

Dry Thermometer.										
Mean of 26 days ...	74·6	74·1	73·6	73·2	74·6	78·0	82·5	84·9	86·3	87·1
Diurnal variation ...	1·4	0·9	0·4	0·0	1·4	4·8	9·3	11·7	13·1	13·9
Wet Thermometer.										
Mean of 26 days ...	73·6	73·2	72·7	72·5	73·3	74·9	76·8	77·0	77·3	77·8
Diurnal variation ...	0·1	0·7	0·2	0·0	0·8	2·4	4·3	4·5	4·8	5·3
Tension of vapour ...	·804	·794	·780	·777	·791	·816	·839	·821	·818	·829

Observatory at Cocos Island.—Hourly observations made

Dry Thermometer.										
Mean of 27 days ...	77·5	77·4	77·4	77·1	77·5	78·8	80·6	81·9	83·5	83·8
Diurnal variation ...	0·4	0·3	0·3	0·0	0·4	1·7	3·5	4·8	6·4	6·7
Wet Thermometer.										
Mean of 27 days ...	73·6	73·6	73·6	73·5	73·7	74·5	75·7	76·4	77·5	77·6
Diurnal variation ...	0·1	0·1	0·1	0·0	0·2	1·0	2·2	2·9	4·0	4·1
Tension of vapour ...	·771	·772	·772	·771	·775	·790	·817	·830	·858	·859

Table C.

made during the Month of May, 1847.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	Sums.	Means.	Tension of vapour.
Dry Thermometer.												
	86·6	85·6	85·4	84·8	83·1	81·0	79·6	78·9	78·3	1538·0	80·9	
	12·6	11·6	11·4	10·8	9·1	7·0	5·6	4·9	4·3			
Wet Thermometer.												
	78·9	78·8	78·6	78·5	77·9	77·2	77·0	76·6	76·3	1459·7	76·8	·859
	5·6	5·5	5·3	5·2	4·6	3·9	3·7	3·3	3·0			
	·881	·889	·883	·885	·879	·874	·881	·873	·867	.....	·859	

made during the Month of June, 1847.

Dry Thermometer.												
	87·2	86·7	86·1	84·5	83·0	80·6	79·6	78·7	78·2	1533·5	80·7	
	14·0	13·5	12·9	11·3	9·8	7·4	6·4	5·5	5·0			
Wet Thermometer.												
	77·9	77·8	77·6	77·1	76·8	76·2	75·7	75·4	75·1	1438·7	75·7	·817
	5·4	5·3	5·1	4·6	4·3	3·7	3·2	2·9	2·6			
	·832	·834	·833	·830	·835	·837	·828	·826	·821	.....	·817	

during the Months of August and September, 1848.

Dry Thermometer.												
	83·0	82·1	80·8	79·8	78·8	78·2	78·0	78·1	77·9	1512·2	79·5	
	5·9	5·0	3·8	2·8	1·8	1·2	1·0	1·1	0·9			
Wet Thermometer.												
	77·1	76·8	75·9	75·3	74·5	74·2	74·2	74·1	74·0	1425·8	75·0	·803
	3·6	3·3	2·4	1·8	1·0	0·7	0·7	0·6	0·5			
	·847	·845	·823	·810	·790	·784	·785	·774	·782	.....	·803	

TABLE D.

Variation of the Barometer, corrected to 32°, at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Moulmein	.....	.....	.....	·049	·044	·053	·063	·077	·102	·120	·131
Madras	.....	.....	.....	·023	·022	·027	·032	·047	·064	·075	·073
Nicobar	.....	.....	.....	·022	·024	·025	·026	·042	·066	·085	·098
Samboanga	.....	.....	.....	·025	·029	·036	·045	·065	·083	·091	·090
Penang	.....	.....	.....	·051	·048	·053	·061	·075	·096	·112	·106
Pulo Dinding	.....	.....	.....	·037	·033	·034	·038	·041	·055	·069	·081
Sarawak	·093	·082	·065	·057	·051	·057	·069	·085	·100	·109	·107
Keemah	.....	.....	.....	·031	·035	·040	·048	·066	·084	·087	·087
Pulo Peesang	.....	.....	.....	.....	·057	·056	·066	·088	·108	·111	·116
Singapore	.....	.....	.....	·034	·036	·044	·058	·080	·098	·103	·098
Carimon	.....	.....	.....	.....	.....	·065	·079	·100	·115	·118	·117
Padang	.....	.....	.....	·038	·036	·042	·056	·078	·098	·103	·101
Bencoolen	.....	.....	.....	·028	·028	·024	·030	·032	·053	·065	·062
Batavia, Winter	·078	·064	·052	·045	·046	·053	·068	·089	·110	·114	·107
Batavia, Spring	.....	.....	.....	·037	·040	·055	·066	·083	·101	·108	·103
Cocos	.....	.....	.....	·018	·016	·023	·036	·053	·069	·080	·076

Variation of the Barometer, corrected to 32°, at

June 1846	·084	·081	·062	·054	·049	·054	·065	·083	·097	·103	·102
July	·091	·077	·062	·055	·050	·053	·064	·081	·096	·103	·102
August	·103	·087	·071	·062	·055	·063	·077	·091	·106	·120	·116
Sums	·278	·245	·195	·171	·154	·170	·206	·255	·299	·326	·320
Means and Variation	·093	·082	·065	·057	·051	·057	·069	·085	·100	·109	·107

Variation of the Barometer, corrected to 32°, at

October 1847	.....	.....	.....	·029	·031	·038	·052	·073	·095	·099	·104
November	.....	.....	.....	·041	·040	·048	·062	·085	·106	·111	·107
December	.....	.....	.....	·038	·032	·037	·048	·071	·088	·095	·090
January 1848	.....	.....	.....	·048	·044	·049	·067	·090	·107	·112	·106
Sums	.....	.....	.....	·156	·147	·172	·229	·319	·396	·417	·407
Means	.....	.....	.....	·039	·037	·043	·057	·079	·099	·104	·102
Variation	.....	.....	.....	·038	·036	·042	·056	·078	·098	·103	·101

Variation of the Barometer, corrected to 32°, at

November 1848	.....	.....	.....	·034	·037	·049	·061	·086	·103	·106	·102
December	.....	.....	.....	·035	·035	·040	·056	·074	·093	·100	·095
Means and Variation	.....	.....	.....	·034	·036	·044	·058	·080	·098	·103	·098

TABLE D.

various Stations in the Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·121	·109	·087	·055	·019	·004	·000	·002	·013	·026	·037	.....	.....	·058
·064	·054	·040	·025	·011	·002	·000	·007	·017	·030	·043	.....	.....	·035
·087	·071	·043	·021	·002	·001	·000	·008	·021	·032	·044	.....	.....	·038
·079	·063	·044	·025	·008	·000	·015	·030	·048	·059	·075	.....	.....	·049
·103	·090	·071	·045	·011	·000	·019	·023	·031	·041	·053	.....	.....	·057
·081	·070	·057	·028	·004	·001	·000	·001	·006	·010	·021	.....	.....	·035
·091	·070	·044	·018	·001	·000	·006	·020	·044	·062	·085	·098	·099	·068
·073	·061	·039	·020	·008	·000	·010	·023	·044	·058	·075	.....	.....	·045
·083	·052	·030	·014	·001	·000	·009	·025	·035	·049	·061	.....	.....	·053
·084	·061	·037	·012	·000	·001	·013	·034	·052	·066	·073	.....	.....	·052
·106	·082	·062	·014	·004	·000	·005	·027	·032	·049	.....	.....	.....	·061
·087	·064	·038	·014	·000	·000	·011	·032	·051	·070	·080	.....	.....	·052
·051	·036	·026	·009	·000	·008	·013	·021	·033	·043	·050	.....	.....	·032
·091	·066	·041	·017	·001	·000	·012	·032	·052	·073	·088	·100	·095	·061
·088	·065	·042	·019	·000	·001	·010	·026	·038	·049	·060	.....	.....	·054
·064	·043	·027	·011	·000	·002	·012	·025	·044	·060	·071	.....	.....	·038

Sarawak in Borneo, Eastern Archipelago.

·085	·065	·041	·016	·000	·001	·008	·020	·039	·058	·074	·085	·086	·061
·086	·066	·042	·020	·004	·000	·002	·013	·032	·052	·079	·094	·093	·059
·102	·079	·049	·019	·000	·001	·008	·027	·060	·077	·102	·116	·118	·071
·273	·210	·132	·055	·004	·002	·018	·060	·131	·187	·255	·295	·297	·191
·091	·070	·044	·018	·001	·000	·006	·020	·044	·062	·085	·098	·099	·064

Padang in Sumatra, Eastern Archipelago.

·088	·063	·034	·010	·002	·000	·011	·035	·048	·065	·073	.....	.....	·050
·093	·066	·039	·017	·000	·003	·015	·038	·057	·075	·084	.....	.....	·057
·080	·060	·039	·016	·003	·000	·012	·026	·046	·071	·081	.....	.....	·056
·093	·070	·045	·018	·000	·002	·010	·035	·057	·072	·084	.....	.....	·057
·354	·259	·157	·061	·005	·005	·048	·134	·208	·283	·322	.....	.....	·214
·088	·065	·039	·015	·001	·001	·012	·033	·052	·071	·081	.....	.....	·053
·087	·064	·038	·014	·000	·000	·011	·032	·051	·070	·080	.....	.....	·052

Singapore, Eastern Archipelago.

·086	·061	·036	·012	·000	·002	·016	·043	·059	·069	·076	.....	.....	·054
·082	·062	·038	·013	·001	·000	·010	·026	·045	·064	·071	.....	.....	·050
·084	·061	·037	·012	·000	·001	·013	·034	·052	·066	·073	.....	.....	·052

Table D.

Variation of the Barometer, corrected to 32°, at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
November .....1846...	·080	·066	·050	·045	·047	·053	·070	·091	·112	·114	·106
December	·081	·066	·055	·046	·046	·053	·068	·090	·119	·129	·122
January .....1847...	·066	·050	·041	·051	·055	·067	·082	·104	·117	·118	·111
February	·092	·081	·070	·046	·044	·046	·060	·079	·099	·103	·097
Sums	·319	·263	·216	·188	·192	·219	·280	·364	·447	·464	·436
Means	·080	·066	·054	·047	·048	·055	·070	·091	·112	·116	·109
Variation	·078	·064	·052	·045	·046	·053	·068	·089	·110	·114	·107

Variation of the Barometer, corrected to 32°, at

March .....1847...	.....	.....	.....	·051	·055	·059	·073	·095	·111	·121	·114
April	.....	.....	.....	·054	·054	·054	·062	·080	·099	·103	·101
May	.....	.....	.....	·040	·048	·056	·067	·080	·100	·109	·101
June	.....	.....	.....	·047	·049	·054	·066	·082	·098	·104	·100
Sums	.....	.....	.....	·192	·206	·223	·268	·337	·408	·437	·416
Means	.....	.....	.....	·038	·041	·056	·067	·084	·102	·109	·104
Variation	.....	.....	.....	·037	·040	·055	·066	·083	·101	·108	·103

Variation of the Gaseous Pressure at

Moulmein	.....	.....	.....	·039	·035	·066	·074	·047	·010	·017	·023
Madras	.....	.....	.....	·062	·074	·093	·110	·106	·131	·139	·146
Nicobar	.....	.....	.....	·187	·177	·180	·182	·166	·108	·115	·078
Sambooanga	.....	.....	.....	·227	·230	·224	·245	·198	·147	·108	·124
Penang	.....	.....	.....	·176	·178	·199	·213	·206	·190	·133	·070
Pulo Dinding.....	.....	.....	.....	·244	·262	·270	·285	·257	·231	·151	·128
Sarawak.....	·140	·134	·124	·122	·120	·131	·150	·156	·148	·127	·112
Keemah	.....	.....	.....	·232	·240	·253	·278	·230	·188	·133	·094
Pulo Peesang.....	.....	.....	.....	.....	·131	·139	·147	·151	·163	·130	·096
Singapore	.....	.....	.....	·054	·059	·070	·096	·122	·134	·128	·120
Carimon.....	.....	.....	.....	.....	.....	·141	·151	·144	·140	·129	·129
Padang	.....	.....	.....	·178	·182	·192	·208	·205	·172	·123	·123
Bencoolen	.....	.....	.....	·159	·167	·169	·175	·122	·113	·103	·090
Batavia, Winter.....	·106	·095	·088	·085	·090	·103	·119	·127	·124	·118	·112
Batavia, Spring.....	.....	.....	.....	·085	·102	·117	·133	·129	·122	·112	·110
Cocos.....	.....	.....	.....	·081	·078	·085	·099	·112	·113	·097	·080

Variation of the Gaseous Pressure at

June .....1846...	·142	·142	·128	·125	·126	·135	·154	·162	·148	·121	·114
July	·143	·134	·128	·129	·126	·134	·151	·159	·154	·129	·109
August	·148	·137	·128	·125	·120	·137	·156	·159	·154	·144	·126
Means	·144	·138	·128	·126	·124	·135	·154	·160	·152	·131	·116
Variation	·140	·134	·124	·122	·120	·131	·150	·156	·148	·127	·112

TABLE D.

Batavia in Java, Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·089	·065	·040	·017	·000	·008	·021	·041	·066	·088	·104	·103	·097	·065
·101	·067	·043	·017	·000	·001	·014	·036	·055	·090	·107	·110	·106	·067
·097	·077	·050	·024	·008	·000	·014	·032	·051	·061	·071	·079	·074	·063
·085	·065	·038	·017	·002	·000	·007	·025	·043	·060	·077	·115	·111	·058
·372	·274	·171	·075	·010	·009	·056	·134	·215	·299	·359	·407	·388	·253
·093	·068	·043	·019	·003	·002	·014	·034	·054	·075	·090	·102	·097	·063
·091	·066	·041	·017	·001	·000	·012	·032	·052	·073	·088	·100	·095	·061

Batavia in Java, Eastern Archipelago.

·102	·079	·055	·027	·004	·000	·009	·028	·040	·049	·062	.....	.....	·061
·086	·060	·039	·016	·000	·002	·011	·028	·036	·049	·060	.....	.....	·052
·085	·064	·044	·022	·001	·000	·012	·028	·041	·051	·062	.....	.....	·053
·082	·060	·035	·015	·000	·007	·011	·023	·040	·052	·060	.....	.....	·053
·355	·263	·173	·080	·005	·009	·043	·107	·157	·201	·244	.....	.....	·219
·089	·066	·043	·020	·001	·002	·011	·027	·039	·050	·061	.....	.....	·055
·088	·065	·042	·019	·000	·001	·010	·026	·038	·049	·060	.....	.....	·054

various Stations in the Eastern Archipelago.

·025	·008	·015	·044	·011	·002	·003	·005	·001	·000	·016	.....	.....	·023
·147	·136	·117	·093	·050	·010	·019	·019	·000	·008	·022	.....	.....	·079
·083	·061	·006	·027	·000	·000	·017	·051	·095	·112	·150	.....	.....	·094
·144	·094	·069	·008	·009	·000	·053	·086	·126	·161	·187	.....	.....	·130
·053	·065	·072	·056	·032	·000	·053	·080	·092	·117	·144	.....	.....	·112
·102	·141	·077	·085	·000	·087	·111	·164	·180	·212	·204	.....	.....	·168
·099	·074	·042	·022	·002	·000	·006	·029	·050	·081	·113	·133	·143	·096
·046	·000	·076	·045	·054	·068	·079	·110	·146	·182	·209	.....	.....	·146
·066	·056	·020	·020	·020	·000	·027	·034	·067	·090	·109	.....	.....	·080
·100	·065	·031	·016	·000	·005	·025	·036	·046	·063	·072	.....	.....	·066
·103	·093	·061	·000	·014	·006	·025	·052	·078	·114	.....	.....	.....	·087
·089	·051	·020	·003	·000	·005	·030	·071	·101	·140	·155	.....	.....	·111
·073	·041	·020	·000	·026	·026	·036	·075	·119	·147	·158	.....	.....	·096
·091	·066	·038	·015	·000	·008	·018	·040	·057	·079	·098	·107	·110	·078
·092	·068	·044	·014	·000	·003	·016	·035	·052	·066	·088	.....	.....	·075
·040	·018	·014	·000	·011	·026	·056	·075	·093	·120	·123	.....	.....	·070

Sarawak in Borneo.

·100	·065	·039	·024	·000	·003	·023	·026	·051	·083	·114	·129	·143	·098
·100	·085	·063	·043	·018	·000	·017	·007	·047	·081	·117	·136	·144	·101
·108	·084	·041	·012	·005	·009	·000	·007	·065	·091	·121	·147	·154	·100
·103	·078	·046	·026	·006	·004	·010	·013	·054	·085	·117	·137	·147	·100
·099	·074	·042	·022	·002	·000	·006	·009	·050	·081	·113	·133	·143	·096

TABLE D.

Variation of the Gaseous

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
October.....1847...	.....	.....	.....	·166	·172	·188	·208	·189	·166	·114	·135
November	.....	.....	.....	·177	·180	·190	·208	·203	·172	·140	·138
December	.....	.....	.....	·171	·173	·180	·191	·192	·147	·089	·090
January .....1848...	.....	.....	.....	·214	·218	·228	·242	·253	·219	·164	·151
Sums	.....	.....	.....	·728	·743	·786	·849	·837	·704	·507	·509
Means	.....	.....	.....	·182	·186	·196	·212	·209	·176	·127	·127
Variation	.....	.....	.....	·178	·182	·192	·208	·205	·172	·123	·123

Variation of the Gaseous

November .....1848...	.....	.....	.....	·058	·067	·082	·098	·134	·141	·136	·124
December	.....	.....	.....	·050	·052	·057	·095	·111	·127	·121	·116
Means and Variation .	.....	.....	.....	·054	·059	·070	·096	·122	·134	·128	·120

Variation of the Gaseous

November .....1846...	·126	·116	·107	·105	·109	·121	·138	·137	·138	·129	·132
December	·109	·098	·087	·081	·085	·098	·116	·122	·124	·120	·116
January .....1847...	·088	·075	·073	·090	·098	·118	·128	·145	·136	·131	·116
February	·107	·094	·091	·070	·073	·080	·100	·109	·102	·098	·088
Sums	·430	·383	·358	·346	·365	·417	·482	·513	·500	·478	·452
Means	·107	·096	·089	·086	·091	·104	·120	·128	·125	·119	·113
Variation	·106	·095	·088	·085	·090	·103	·119	·127	·124	·118	·112

Variation of the Gaseous

March .....1847...	.....	.....	.....	·091	·104	·115	·134	·136	·131	·135	·126
April	.....	.....	.....	·086	·106	·119	·127	·120	·116	·095	·093
May	.....	.....	.....	·093	·115	·131	·154	·140	·130	·125	·112
June	.....	.....	.....	·076	·088	·107	·122	·124	·115	·098	·112
Sums	.....	.....	.....	·346	·413	·472	·537	·520	·492	·453	·443
Means	.....	.....	.....	·086	·103	·118	·134	·130	·123	·113	·111
Variation	.....	.....	.....	·085	·102	·117	·133	·129	·122	·112	·110

Table D.

Pressure at Padang in Sumatra, Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
·092	·059	·026	·000	·005	·006	·015	·061	·097	·137	·145	.....	.....	·106
·110	·054	·031	·004	·000	·009	·043	·081	·097	·135	·154	.....	.....	·115
·063	·041	·005	·000	·012	·019	·039	·062	·099	·150	·159	.....	.....	·106
·107	·068	·031	·026	·000	·003	·038	·098	·128	·153	·179	.....	.....	·135
·372	·222	·093	·030	·017	·037	·135	·302	·421	·575	·637	.....	.....	·462
·093	·055	·024	·007	·004	·009	·034	·075	·105	·144	·159	.....	.....	·115
·089	·051	·020	·003	·000	·005	·030	·071	·101	·140	·155	.....	.....	·111

Pressure Vapour at Singapore.

·101	·071	·033	·004	·000	·003	·026	·044	·053	·068	·074	.....	.....	·071
·098	·060	·060	·028	·000	·008	·023	·028	·038	·059	·070	.....	.....	·062
·100	·065	·031	·016	·000	·005	·025	·036	·046	·063	·072	.....	.....	·066

Pressure at Batavia.—Winter.

·104	·065	·054	·024	·000	·021	·025	·049	·079	·102	·126	·124	·129	·094
·087	·060	·031	·010	·000	·012	·029	·048	·061	·097	·117	·117	·122	·081
·104	·085	·048	·024	·005	·000	·014	·044	·057	·063	·084	·084	·086	·080
·074	·060	·025	·007	·000	·003	·007	·024	·034	·060	·069	·108	·109	·063
·369	·270	·158	·065	·005	·036	·075	·165	·231	·322	·396	·433	·446	·318
·092	·067	·039	·016	·001	·009	·019	·041	·058	·080	·099	·108	·111	·079
·091	·066	·038	·015	·000	·008	·018	·040	·057	·079	·098	·107	·110	·078

Pressure at Batavia.—Spring.

·111	·086	·062	·022	·000	·000	·021	·042	·061	·072	·103	.....	.....	·083
·076	·051	·035	·007	·000	·008	·021	·043	·060	·075	·103	.....	.....	·073
·088	·075	·048	·018	·003	·000	·018	·039	·045	·063	·080	.....	.....	·079
·097	·064	·036	·014	·000	·010	·009	·019	·045	·059	·072	.....	.....	·068
·372	·276	·181	·061	·003	·018	·069	·143	·211	·269	·358	.....	.....	·303
·093	·069	·045	·015	·001	·004	·017	·036	·053	·067	·089	.....	.....	·076
·092	·068	·044	·014	·000	·003	·016	·035	·052	·066	·088	.....	.....	·075

TABLE D.

Observatory at Moulmein.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
									Portable Barometer, 28 English		
Mean of 7 days	.....	.....	.....	1·863	1·858	1·866	1·876	1·895	1·938	1·965	1·986
Barom. corr. to 32°...	.....	.....	.....	1·755	1·750	1·759	1·769	1·783	1·808	1·826	1·837
Gaseous pressure ...	.....	.....	.....	0·929	0·925	0·956	0·964	0·937	0·900	0·907	0·913

Observatory at Madras.—Hourly observations

									Portable Barometer, 28 English		
Mean of 34 days ...	.....	.....	.....	1·780	1·779	1·783	1·787	1·804	1·830	1·852	1·857
Barom. corr. to 32°...	.....	.....	.....	1·668	1·667	1·672	1·677	1·692	1·709	1·720	1·718
Gaseous pressure ...	.....	.....	.....	0·858	0·870	0·889	0·906	0·902	0·927	0·935	0·942

Observatory at Car Nicobar.—Hourly observations

									Portable Barometer, 28 English		
Mean of 5 days	.....	.....	.....	2·017	2·019	2·020	2·022	2·040	2·074	2·101	2·122
Barom. corr. to 32°...	.....	.....	.....	1·918	1·920	1·921	1·922	1·938	1·962	1·981	1·994
Gaseous pressure ...	.....	.....	.....	1·168	1·158	1·161	1·163	1·147	1·089	1·096	1·059

Observatory at Sambooanga.—Hourly observations

									Standard Barometer, 28 English		
Mean of 6 days	.....	.....	.....	1·957	1·960	1·967	1·976	2·004	2·035	2·051	2·053
Barom. corr. to 32°...	.....	.....	.....	1·837	1·841	1·848	1·857	1·877	1·895	1·903	1·902
Gaseous pressure ...	.....	.....	.....	1·077	1·080	1·074	1·095	1·048	0·997	0·958	0·974

Observatory at Penang.—Hourly observations

									Portable Barometer, 28 English		
Mean of 3 days	.....	.....	.....	1·986	1·981	1·983	1·991	2·007	2·031	2·055	2·057
Barom. corr. to 32°...	.....	.....	.....	1·876	1·873	1·878	1·886	1·900	1·921	1·937	1·931
Gaseous pressure ...	.....	.....	.....	1·067	1·069	1·090	1·104	1·097	1·081	1·024	0·961

Observatory at Pulo Dinding.—Hourly observations

									Portable Barometer, 28 English		
Mean of 2 days	.....	.....	.....	2·099	2·092	2·091	2·093	2·096	2·117	2·142	2·165
Barom. corr. to 32°...	.....	.....	.....	1·992	1·988	1·989	1·993	1·996	2·010	2·024	2·036
Gaseous pressure ...	.....	.....	.....	1·212	1·230	1·238	1·253	1·225	1·199	1·119	1·096

Observatory at Sarawak.—Hourly observations

									Standard Barometer, 28 English		
Mean of 26 days ...	2·018	2·005	1·993	1·985	1·980	1·985	1·994	2·012	2·028	2·040	2·044
Barom. corr. to 32°...	1·891	1·888	1·869	1·861	1·856	1·861	1·872	1·890	1·904	1·910	1·909
Gaseous pressure ...	1·001	1·001	0·987	0·984	0·985	0·994	1·013	1·021	1·007	0·980	0·973

Table D,

made during the Month of April, 1849.

23.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
inches + the numbers in the Table.												
1·987	1·981	1·961	1·929	1·889	1·870	1·861	1·847	1·846	1·853	1·862		
1·827	1·815	1·793	1·761	1·725	1·710	1·706	1·708	1·719	1·732	1·743		
0·915	0·898	0·905	0·934	0·901	0·892	0·893	0·895	0·891	0·890	0·906		

made during the Months of August and September, 1849.

inches + the numbers in the Table.												
1·853	1·846	1·834	1·819	1·801	1·788	1·781	1·781	1·786	1·797	1·808		
1·709	1·699	1·685	1·670	1·656	1·647	1·645	1·652	1·662	1·675	1·688		
0·943	0·932	0·913	0·889	0·846	0·806	0·815	0·815	0·796	0·804	0·818		

made during the Month of February, 1849.

inches + the numbers in the Table.												
2·117	2·102	2·075	2·050	2·029	2·026	2·023	2·023	2·030	2·038	2·047		
1·983	1·967	1·939	1·917	1·898	1·897	1·896	1·904	1·917	1·928	1·940		
1·064	1·042	0·987	1·008	0·981	0·981	0·998	1·032	1·076	1·093	1·131		

made during the Month of May, 1848.

inches + the numbers in the Table.												
2·039	2·026	2·012	1·994	1·979	1·968	1·978	1·988	2·000	2·009	2·019		
1·891	1·875	1·856	1·837	1·820	1·812	1·827	1·842	1·860	1·871	1·887		
0·994	0·944	0·919	0·858	0·859	0·850	0·903	0·936	0·976	1·011	1·037		

made during the Month of January, 1849.

inches + the numbers in the Table.												
2·062	2·051	2·030	2·004	1·971	1·959	1·975	1·974	1·976	1·984	1·993		
1·928	1·915	1·896	1·870	1·836	1·825	1·844	1·848	1·856	1·866	1·878		
0·944	0·956	0·963	0·947	0·923	0·891	0·944	0·971	0·983	1·008	1·035		

made during the Month of January, 1849.

inches + the numbers in the Table.												
2·177	2·173	2·160	2·124	2·098	2·087	2·079	2·075	2·073	2·076	2·086		
2·036	2·025	2·012	1·983	1·959	1·956	1·955	1·956	1·961	1·965	1·976		
1·070	1·109	1·045	1·053	0·968	1·055	1·079	1·132	1·148	1·180	1·172		

made during the Month of June, 1846.

inches + the numbers in the Table.												
2·032	2·015	1·994	1·970	1·953	1·951	1·955	1·965	1·978	1·995	2·011	2·019	2·020
1·892	1·872	1·848	1·823	1·807	1·808	1·815	1·827	1·846	1·865	1·881	1·892	1·893
0·959	0·924	0·898	0·883	0·859	0·862	0·882	0·885	0·910	0·942	0·973	0·988	1·002

Table D.

Observatory at Sarawak.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
											Standard Barometer, 28 English
Mean of 27 days ...	2·013	1·998	1·983	1·974	1·969	1·972	1·983	1·998	2·015	2·027	2·029
Barom. corr. to 32°...	1·888	1·874	1·859	1·852	1·847	1·850	1·861	1·878	1·893	1·900	1·899
Gaseous pressure ...	1·013	1·004	0·998	0·999	0·996	1·004	1·021	1·029	1·024	0·999	0·979

Observatory at Sarawak.—Hourly observations

											Standard Barometer, 28 English
Mean of 19 days ...	2·034	2·017	2·000	1·991	1·984	1·990	2·003	2·017	2·035	2·051	2·053
Barom. corr. to 32°...	1·910	1·894	1·878	1·869	1·862	1·870	1·884	1·898	1·913	1·927	1·923
Gaseous pressure ...	1·051	1·040	1·031	1·028	1·023	1·040	1·059	1·062	1·057	1·047	1·029

Observatory at Keemah.—Hourly observations

											Standard Barometer, 28 English
Mean of 10 days ...	.....	.....	.....	1·980	1·981	1·986	1·994	2·016	2·049	2·060	2·068
Barom. corr. to 32°...	.....	.....	.....	1·861	1·865	1·870	1·878	1·896	1·914	1·917	1·917
Gaseous pressure ...	.....	.....	.....	1·096	1·104	1·117	1·142	1·094	1·052	0·997	0·958

Observatory at Pulo Peesang.—Hourly observations

											Standard Barometer, 28 English
Mean of 5 days.....	.....	.....	.....	.....	2·066	2·064	2·074	2·100	2·125	2·137	2·162
Barom. corr. to 32°...	.....	.....	.....	.....	1·962	1·961	1·971	1·993	2·013	2·016	2·021
Gaseous pressure ...	.....	.....	.....	.....	1·104	1·112	1·120	1·124	1·136	1·103	1·069

Observatory at Singapore.—Hourly observations

											Standard Barometer, 28 English
Mean of 16 days ...	.....	.....	.....	2·026	2·029	2·041	2·053	2·075	2·092	2·098	2·097
Barom. corr. to 32°...	.....	.....	.....	1·891	1·894	1·906	1·918	1·943	1·960	1·963	1·959
Gaseous pressure ...	.....	.....	.....	1·028	1·037	1·052	1·068	1·104	1·111	1·106	1·094

Observatory at Singapore.—Hourly observations

											Standard Barometer, 28 English
Mean of 14 days ...	.....	.....	.....	2·017	2·017	2·022	2·036	2·053	2·073	2·083	2·082
Barom. corr. to 32°...	.....	.....	.....	1·887	1·887	1·892	1·908	1·926	1·945	1·952	1·947
Gaseous pressure ...	.....	.....	.....	1·046	1·048	1·053	1·091	1·107	1·123	1·117	1·112

Observatory at Carimon Island.—Hourly observations

											Standard Barometer, 28 English
Mean of 6 days.....	.....	.....	.....	.....	.....	2·075	2·089	2·116	2·146	2·152	2·153
Barom. corr. to 32°...	.....	.....	.....	.....	.....	1·968	1·982	2·003	2·018	2·021	2·020
Gaseous pressure ...	.....	.....	.....	.....	.....	1·125	1·235	1·128	1·124	1·113	1·113

Table D.

made during the Month of July, 1846.

23.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
inches + the numbers in the Table.												
2·018	2·003	1·982	1·960	1·944	1·937	1·939	1·946	1·961	1·979	2·003	2·018	2·017
1·883	1·863	1·839	1·817	1·801	1·797	1·799	1·810	1·829	1·849	1·876	1·891	1·890
0·970	0·955	0·933	0·913	0·888	0·870	0·887	0·877	0·917	0·951	0·987	1·006	1·014

made during the Month of August, 1846.

inches + the numbers in the Table.												
2·044	2·026	2·000	1·972	1·953	1·949	1·953	1·969	1·997	2·011	2·036	2·048	2·049
1·909	1·886	1·856	1·826	1·807	1·808	1·815	1·834	1·867	1·884	1·909	1·923	1·925
1·011	0·987	0·944	0·915	0·908	0·912	0·903	0·910	0·968	0·994	1·024	1·050	1·057

made during the Month of June, 1848.

inches + the numbers in the Table.												
2·062	2·052	2·028	2·001	1·984	1·976	1·981	1·991	2·006	2·018	2·030		
1·903	1·891	1·869	1·850	1·838	1·830	1·840	1·853	1·874	1·888	1·905		
0·910	0·864	0·940	0·909	0·918	0·932	0·943	0·974	1·010	1·046	1·073		

made during the Month of January, 1846.

inches + the numbers in the Table.												
2·124	2·097	2·074	2·052	2·030	2·031	2·030	2·037	2·047	2·062	2·072		
1·988	1·957	1·935	1·919	1·906	1·905	1·914	1·930	1·940	1·954	1·966		
1·039	1·029	0·993	0·993	0·993	0·973	1·000	1·037	1·040	1·063	1·082		

made during the Month of November, 1848.

inches + the numbers in the Table.												
2·081	2·058	2·033	2·009	1·997	1·998	2·011	2·038	2·054	2·064	2·068		
1·943	1·918	1·893	1·869	1·857	1·859	1·873	1·900	1·916	1·926	1·933		
1·071	1·041	1·003	0·974	0·970	0·973	0·996	1·014	1·023	1·038	1·044		

made during the Month of December, 1848.

inches + the numbers in the Table.												
2·069	2·050	2·027	2·002	1·989	1·987	1·997	2·010	2·029	2·048	2·055		
1·934	1·914	1·890	1·865	1·853	1·852	1·862	1·878	1·897	1·916	1·923		
1·094	1·056	1·026	1·024	0·996	1·004	1·019	1·024	1·034	1·055	1·066		

made during the Month of January, 1846.

inches + the numbers in the Table.												
2·143	2·124	2·105	2·058	2·046	2·039	2·043	2·053	2·052	2·064			
2·009	1·985	1·965	1·917	1·907	1·903	1·908	1·930	1·935	1·952			
1·087	1·077	1·045	0·954	0·998	0·990	1·009	1·136	1·062	1·098			

TABLE D.

Observatory at Padang.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
											Standard Barometer, 28 English
Mean of 13 days ...	.....	.....	.....	2·004	2·006	2·013	2·027	2·050	2·080	2·098	2·111
Barom. corr. to 32°...	.....	.....	.....	1·890	1·892	1·899	1·913	1·934	1·956	1·960	1·965
Gaseous pressure ...	.....	.....	.....	1·143	1·149	1·165	1·185	1·166	1·143	1·091	1·112

Observatory at Padang.—Hourly observations

											Standard Barometer, 28 English
Mean of 26 days ...	.....	.....	.....	2·004	2·003	2·009	2·023	2·048	2·077	2·096	2·100
Barom. corr. to 32°...	.....	.....	.....	1·888	1·887	1·895	1·909	1·932	1·953	1·958	1·954
Gaseous pressure ...	.....	.....	.....	1·131	1·134	1·144	1·162	1·157	1·126	1·094	1·087

Observatory at Padang.—Hourly observations

											Standard Barometer, 28 English
Mean of 26 days ...	.....	.....	.....	1·970	1·967	1·972	1·983	2·006	2·031	2·049	2·055
Barom. corr. to 32°...	.....	.....	.....	1·857	1·851	1·856	1·867	1·890	1·907	1·914	1·909
Gaseous pressure ...	.....	.....	.....	1·108	1·110	1·117	1·128	1·129	1·084	1·026	1·027

Observatory at Pedang.—Hourly observations

											Standard Barometer, 28 English
Mean of 13 days ...	.....	.....	.....	1·985	1·981	1·986	2·004	2·027	2·052	2·068	2·070
Barom. corr. to 32°...	.....	.....	.....	1·869	1·865	1·870	1·888	1·911	1·928	1·933	1·927
Gaseous pressure ...	.....	.....	.....	1·102	1·106	1·116	1·130	1·141	1·107	1·052	1·039

Observatory at Poolo Bay.—Hourly observations

											Portable Barometer, 28 English
Mean of 5 days	.....	.....	.....	1·954	1·952	1·948	1·954	1·962	1·990	2·010	2·015
Barom. corr. to 32°...	.....	.....	.....	1·855	1·855	1·851	1·857	1·859	1·880	1·892	1·889
Gaseous pressure ...	.....	.....	.....	1·035	1·043	1·045	1·051	0·998	0·989	0·979	0·966

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 19 days ...	2·000	1·983	1·967	1·961	1·962	1·968	1·985	2·006	2·032	2·042	2·039
Barom. corr. to 32°...	1·873	1·859	1·843	1·838	1·840	1·846	1·863	1·884	1·905	1·907	1·899
Gaseous pressure ...	1·023	1·013	1·004	1·002	1·006	1·018	1·035	1·034	1·035	1·026	1·029

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 26 days ...	1·999	1·984	1·973	1·963	1·962	1·969	1·984	2·007	2·040	2·058	2·056
Barom. corr. to 32°...	1·875	1·860	1·849	1·840	1·840	1·847	1·862	1·884	1·913	1·923	1·916
Gaseous pressure ...	1·025	1·014	1·003	0·997	1·001	1·014	1·032	1·038	1·040	1·036	1·032

TABLE D.

made during the Month of October, 1847.

23.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
inches + the numbers in the Table.												
2·103	2·080	2·051	2·027	2·017	2·009	2·015	2·031	2·039	2·050	2·056	.....	.....
1·949	1·924	1·895	1·871	1·863	1·861	1·872	1·896	1·909	1·926	1·934	.....	.....
1·069	1·036	1·003	0·977	0·982	0·983	0·992	1·038	1·074	1·114	1·122	.....	.....

made during the Month of November, 1847.

inches + the numbers in the Table.												
2·091	2·069	2·045	2·020	2·001	1·998	2·005	2·020	2·034	2·049	2·055		
1·940	1·913	1·886	1·864	1·847	1·850	1·862	1·885	1·904	1·922	1·931		
1·064	1·008	0·985	0·958	0·954	0·963	0·997	1·035	1·051	1·089	1·108		

made during the Month of December, 1847.

inches + the numbers in the Table.												
2·050	2·038	2·019	1·996	1·978	1·970	1·974	1·983	1·995	2·014	2·022		
1·899	1·879	1·858	1·835	1·822	1·819	1·831	1·845	1·865	1·890	1·900		
1·000	0·978	0·942	0·937	0·949	0·956	0·976	0·999	1·036	1·087	1·096		

made during the Month of January, 1848.

inches + the numbers in the Table.												
2·065	2·047	2·027	2·000	1·980	1·977	1·979	1·996	2·010	2·020	2·029		
1·914	1·891	1·866	1·839	1·821	1·823	1·831	1·856	1·878	1·893	1·905		
0·995	0·956	0·919	0·914	0·888	0·891	0·926	0·986	1·016	1·041	1·067		

made during the Months of August and September, 1847.

inches + the numbers in the Table.												
2·006	1·994	1·982	1·960	1·948	1·955	1·958	1·960	1·970	1·975	1·980	.....	.....
1·878	1·863	1·853	1·836	1·827	1·835	1·840	1·848	1·860	1·870	1·877	.....	.....
0·949	0·917	0·896	0·876	0·902	0·902	0·912	0·951	0·995	1·023	1·034	.....	.....

made during the Month of November, 1846.

inches + the numbers in the Table.												
2·028	2·007	1·983	1·959	1·941	1·947	1·955	1·972	1·994	2·013	2·027	2·026	2·017
1·882	1·858	1·833	1·810	1·793	1·801	1·814	1·834	1·859	1·881	1·897	1·896	1·890
1·001	0·962	0·951	0·921	0·897	0·918	0·922	0·946	0·969	0·999	1·023	1·021	1·026

made during the Month of December, 1846.

inches + the numbers in the Table.												
2·041	2·007	1·984	1·957	1·940	1·938	1·948	1·965	1·981	2·014	2·031	2·031	2·027
1·895	1·861	1·837	1·811	1·794	1·795	1·808	1·830	1·849	1·884	1·901	1·904	1·900
1·003	0·976	0·947	0·926	0·916	0·928	0·945	0·964	0·977	1·013	1·033	1·033	1·038

Table D.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
											Standard Barometer, 28 English
Mean of 25 days ...	1·997	1·979	1·969	1·977	1·981	1·992	2·007	2·029	2·045	2·052	2·050
Barom. corr. to 32°...	1·870	1·854	1·845	1·855	1·859	1·871	1·886	1·908	1·921	1·922	1·915
Gaseous pressure ...	1·021	1·008	1·006	1·023	1·031	1·051	1·061	1·078	1·069	1·064	1·049

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 24 days ...	2·018	2·006	1·994	1·970	1·968	1·969	1·982	2·001	2·023	2·033	2·032
Barom. corr. to 32°...	1·892	1·881	1·870	1·846	1·844	1·846	1·860	1·879	1·899	1·903	1·897
Gaseous pressure ...	1·028	1·015	1·012	0·991	0·994	1·001	1·021	1·030	1·023	1·019	1·009

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 27 days ...	.....	.....	.....	1·993	1·994	1·998	2·012	2·034	2·053	2·068	2·067
Barom. corr. to 32°...	.....	.....	.....	1·866	1·870	1·874	1·888	1·910	1·926	1·936	1·929
Gaseous pressure ...	.....	.....	.....	0·996	1·009	1·020	1·039	1·041	1·036	1·040	1·031

Observatory at Batavia.—Hourly observations

											Staudard Barometer, 28 English
Mean of 26 days ...	.....	.....	.....	1·999	1·998	1·997	2·004	2·024	2·046	2·058	2·061
Barom. corr. to 32°...	.....	.....	.....	1·874	1·874	1·874	1·882	1·900	1·919	1·923	1·921
Gaseous pressure ...	.....	.....	.....	1·008	1·028	1·041	1·049	1·042	1·038	1·017	1·015

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 26 days ...	.....	.....	.....	1·983	1·989	1·995	2·005	2·021	2·046	2·066	2·062
Barom. corr. to 32°...	.....	.....	.....	1·859	1·867	1·875	1·886	1·899	1·919	1·928	1·920
Gaseous pressure ...	.....	.....	.....	1·027	1·049	1·065	1·088	1·074	1·064	1·059	1·046

Observatory at Batavia.—Hourly observations

											Standard Barometer, 28 English
Mean of 26 days ...	.....	.....	.....	1·984	1·983	1·988	1·997	2·016	2·037	2·054	2·056
Barom. corr. to 32°...	.....	.....	.....	1·862	1·864	1·869	1·881	1·897	1·913	1·919	1·915
Gaseous pressure ...	.....	.....	.....	1·058	1·070	1·089	1·104	1·106	1·097	1·080	1·094

Observatory at Cocos Island.—Hourly observations

											Standard Barometer, 28 English
Mean of 27 days ...	.....	.....	.....	2·059	2·057	2·064	2·077	2·094	2·113	2·129	2·131
Barom. corr. to 32°...	.....	.....	.....	1·935	1·933	1·940	1·953	1·970	1·986	1·997	1·993
Gaseous pressure ...	.....	.....	.....	1·164	1·161	1·168	1·182	1·195	1·196	1·180	1·163

TABLE D.

23.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
made during the Month of January, 1847.												
inches + the numbers in the Table.												
2·040	2·022	1·998	1·974	1·958	1·950	1·961	1·976	1·991	2·000	2·007	2·014	2·008
1·901	1·881	1·854	1·828	1·812	1·804	1·818	1·836	1·855	1·865	1·875	1·883	1·878
1·037	1·018	0·981	0·957	0·938	0·933	0·947	0·977	0·990	0·996	1·017	1·017	1·019
made during the Month of February, 1847.												
inches + the numbers in the Table.												
2·023	2·005	1·981	1·961	1·945	1·941	1·945	1·960	1·975	1·991	2·007	2·044	2·039
1·885	1·865	1·838	1·817	1·802	1·800	1·807	1·825	1·843	1·860	1·877	1·915	1·911
0·995	0·981	0·946	0·928	0·921	0·924	0·928	0·945	0·955	0·981	0·990	1·029	1·030
made during the Month of March, 1847.												
inches + the numbers in the Table.												
2·058	2·038	2·016	1·989	1·966	1·961	1·968	1·983	1·993	2·000	2·009		
1·917	1·894	1·870	1·842	1·819	1·815	1·824	1·843	1·855	1·864	1·877		
1·016	0·991	0·967	0·927	0·903	0·905	0·926	0·947	0·966	0·977	1·008		
made during the Month of April, 1847.												
inches + the numbers in the Table.												
2·049	2·027	2·007	1·984	1·967	1·968	1·974	1·988	1·994	2·004	2·012		
1·906	1·880	1·859	1·836	1·820	1·822	1·831	1·848	1·856	1·869	1·880		
0·998	0·973	0·957	0·929	0·922	0·930	0·943	0·965	0·982	0·997	1·025		
during the Months of May, 1847.												
inches + the numbers in the Table.												
2·051	2·034	2·014	1·989	1·968	1·966	1·975	1·987	1·996	2·005	2·013		
1·904	1·883	1·863	1·841	1·820	1·819	1·831	1·847	1·860	1·870	1·881		
1·022	1·009	0·982	0·952	0·937	0·934	0·952	0·973	0·979	0·997	1·014		
made during the Month of June, 1847.												
inches + the numbers in the Table.												
2·045	2·026	2·002	1·981	1·966	1·969	1·969	1·977	1·991	2·000	2·007		
1·897	1·875	1·850	1·830	1·815	1·822	1·826	1·838	1·855	1·867	1·875		
1·079	1·046	1·018	0·996	0·982	0·992	0·991	1·001	1·027	1·041	1·054		
made during the Months of August and September, 1848.												
inches + the numbers in the Table.												
2·121	2·103	2·087	2·068	2·055	2·054	2·061	2·072	2·088	2·104	2·115		
1·981	1·960	1·944	1·928	1·917	1·919	1·929	1·942	1·961	1·977	1·988		
1·123	1·101	1·097	1·083	1·094	1·109	1·139	1·158	1·176	1·203	1·206		

TABLE E.

Diurnal variation of the Standard Thermometer at

Astron. Mean Time.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Moulmein	.....	.....	.....	0·4	0·5	0·2	0·0	1·7	7·6	11·4	15·4
Madras	.....	.....	.....	1·2	0·8	0·3	0·0	1·2	4·6	8·0	10·5
Nicobar	.....	.....	.....	0·0	0·2	0·2	0·4	1·0	4·3	7·2	10·5
Sambooanga	.....	.....	.....	0·2	0·1	0·1	0·0	3·4	9·1	10·7	11·4
Penang	.....	.....	.....	1·1	0·9	0·1	0·0	0·7	2·1	6·0	10·0
Pulo Dinding	.....	.....	.....	1·9	1·0	0·5	0·0	0·4	2·7	7·4	12·7
Sarawak	1·7	1·4	1·1	0·8	0·5	0·3	0·1	0·0	0·9	2·8	4·7
Keemah	.....	.....	.....	0·9	0·5	0·3	0·0	2·1	8·1	11·0	14·2
Pulo Peesang	.....	.....	.....	0·7	0·0	0·2	1·1	2·5	6·0	10·6	13·7
Singapore	.....	.....	.....	0·9	0·8	0·6	0·3	0·0	0·4	1·1	1·7
Carimon	.....	.....	.....	.....	.....	0·3	0·0	2·2	5·3	8·6	10·8
Padang	.....	.....	.....	0·6	0·3	0·1	0·0	1·1	5·1	9·7	12·6
Bencoolen	.....	.....	.....	0·5	0·2	0·1	0·0	2·0	4·9	7·7	10·2
Batavia, Winter	1·9	1·6	1·2	0·7	0·5	0·2	0·0	0·5	2·1	4·3	6·2
Batavia, Spring	.....	.....	.....	1·1	0·7	0·2	0·0	0·6	2·6	5·6	7·5
Cocos	.....	.....	.....	0·3	0·1	0·2	0·0	0·4	1·5	3·4	4·8

Observatory at Moulmein.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Noon.
Standard Thermometer.													
Mean of 7 days	.....	.....	.....	77·7	77·5	77·2	77·0	78·7	84·6	88·4	92·4	97·1	99·7
Diurnal variation	.....	.....	.....	0·4	0·5	0·2	0·0	1·7	7·6	11·4	15·4	20·1	22·7

Observatory at Madras.—Hourly observations

Standard Thermometer.												
Mean of 34 days	.....	.....	.....	78·8	78·4	77·9	77·6	78·8	82·2	85·6	88·1	90·2	92·0
Diurnal variation	.....	.....	.....	1·2	0·8	0·3	0·0	1·2	4·6	8·0	10·5	12·6	14·4

Observatory at Car Nicobar.—Hourly observations

Standard Thermometer.												
Mean of 5 days	.....	.....	.....	73·8	74·0	74·0	74·2	74·8	78·1	81·0	84·3	86·6	87·4
Diurnal variation	.....	.....	.....	0·0	0·2	0·2	0·4	1·0	4·3	7·2	10·5	12·8	13·6

Observatory at Sambooanga.—Hourly observations

Standard Thermometer.												
Mean of 6 days	.....	.....	.....	74·9	74·8	74·8	74·7	78·1	83·8	85·4	86·1	84·7	86·5
Diurnal variation	.....	.....	.....	0·2	0·1	0·1	0·0	3·4	9·1	10·7	11·4	10·0	11·8

Table E.

various stations in the Eastern Archipelago.

23.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean.
20·1	22·7	23·4	23·7	23·2	19·7	17·6	11·5	15·3	17·2	18·2	.....	.....	11·4
12·6	14·4	15·5	15·2	13·9	12·6	10·4	7·7	6·0	5·0	4·4	.....	.....	7·6
12·8	13·6	14·3	13·2	12·2	12·1	11·0	7·8	5·7	4·7	3·6	.....	.....	7·1
10·0	11·8	13·5	14·3	13·9	12·7	10·7	8·7	8·4	6·1	5·0	.....	.....	7·8
12·4	13·3	12·0	10·8	11·0	9·5	8·2	6·2	4·8	4·0	3·6	.....	.....	6·2
17·9	19·4	20·6	18·6	16·8	13·0	9·7	6·8	5·1	4·3	3·8	.....	.....	8·5
6·3	7·8	8·6	8·9	8·6	7·7	6·9	5·7	3·9	3·2	2·8	2·4	2·0	3·7
16·4	17·9	15·3	13·3	12·0	11·1	9·3	7·8	6·2	5·3	4·5	.....	.....	8·2
14·9	15·0	10·9	8·4	7·6	5·2	3·7	3·2	3·5	2·7	.....	.....	.....	6·1
2·1	2·4	2·6	2·5	2·5	2·3	2·0	1·8	1·7	1·6	1·2	.....	.....	1·5
13·9	14·4	14·4	15·0	13·1	11·8	9·3	5·8	4·3	3·3	.....	.....	.....	8·3
15·0	16·6	17·5	16·8	15·1	12·8	10·3	7·4	5·4	4·0	3·1	.....	.....	8·1
11·0	12·4	14·8	10·0	8·9	9·0	7·8	6·1	4·9	3·3	2·6	.....	.....	6·1
7·6	8·4	9·0	9·1	8·7	8·0	6·9	5·5	4·5	3·9	3·4	3·1	2·5	4·2
9·0	10·1	10·3	10·2	10·1	9·3	8·2	6·6	5·6	4·8	4·1	.....	.....	5·6
6·4	6·8	6·8	5·8	4·7	3·5	2·4	1·5	1·2	1·0	0·9	.....	.....	2·6

made during the Month of April, 1849.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.
Standard Thermometer.												
100·4 23·4	100·7 23·7	99·2 22·2	96·7 19·7	94·6 17·6	88·5 11·5	84·5 7·5	82·6 5·6	81·6 4·6	.....	.....	1679·1	88·4

made during the Months of August and September, 1849.

Standard Thermometer.												
93·1 15·5	92·8 15·2	91·5 13·9	90·2 12·6	88·0 10·4	85·3 7·7	83·6 6·0	82·6 5·0	82·0 4·4	.....	.....	1618·7	85·2

made during the Month of February, 1849.

Standard Thermometer.												
88·1 14·3	87·0 13·2	86·0 12·2	85·9 12·1	84·8 11·0	81·6 7·8	79·5 5·7	78·5 4·7	77·4 3·6	.....	.....	1537·0	80·9

made during the Month of May, 1848.

Standard Thermometer.												
88·2 13·5	89·0 14·3	88·6 13·9	87·4 12·7	85·4 10·7	83·4 8·7	81·9 7·2	80·8 6·1	79·7 5·0	.....	.....	1568·2	82·5

Table E.

Observatory at Penang.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Noon.
Standard Thermometer.													
Mean of 5 days	.....	.....	.....	76·6	76·4	75·6	75·6	76·2	77·6	81·5	85·5	87·9	88·8
Diurnal variation ...	.....	.....	.....	1·1	0·9	0·1	0·0	0·7	2·1	6·0	10·0	12·4	13·3

Observatory at Pulo Dinding.—Hourly observations

Standard Thermometer.													
Mean of 3 days	.....	.....	.....	76·0	75·1	74·6	74·1	74·5	76·8	81·5	86·8	92·0	93·5
Diurnal variation ...	.....	.....	.....	1·9	1·0	0·5	0·0	0·4	2·7	7·4	12·7	17·9	19·4

Observatory at Sarawak.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	77·5	77·2	76·8	76·5	76·3	76·1	75·9	75·9	76·9	78·9	80·9	82·6	83·9
Diurnal variation ...	1·6	1·3	0·9	0·6	0·4	0·2	0·0	0·0	1·0	3·0	5·0	6·7	8·0

Observatory at Sarawak.—Hourly observations

Standard Thermometer.													
Mean of 27 days ...	77·0	76·8	76·4	76·1	75·9	75·7	75·4	75·3	76·1	77·9	79·5	81·0	82·4
Diurnal variation	1·7	1·5	1·1	0·8	0·6	0·4	0·1	0·0	0·8	2·6	4·2	5·7	7·1

Observatory at Sarawak.—Hourly observations

Standard Thermometer.													
Mean of 19 days ...	76·6	76·3	76·0	75·7	75·4	75·2	74·9	74·9	75·8	77·7	79·6	81·4	83·0
Diurnal variation ...	1·7	1·4	1·1	0·8	0·5	0·3	0·0	0·0	0·9	2·8	4·7	6·5	8·1

Observatory at Keemah.—Hourly observations

Standard Thermometer.													
Mean of 10 days ...	.....	.....	.....	74·3	73·9	73·7	73·4	75·5	81·5	84·4	87·6	89·8	91·3
Diurnal variation ...	.....	.....	.....	0·9	0·5	0·3	0·0	2·1	8·1	11·0	14·2	16·4	17·9

Observatory at Pulo Peesang.—Hourly observations

Standard Thermometer.													
Mean of 5 days	.....	.....	.....	.....	75·9	75·2	75·4	76·3	77·7	81·2	85·8	88·9	90·1
Diurnal variation ...	.....	.....	.....	.....	0·7	0·0	0·2	1·1	2·5	6·0	10·6	13·7	14·9

Observatory at Singapore.—Hourly observations

Standard Thermometer.													
Mean of 16 days ...	.....	.....	.....	79·3	79·2	79·1	78·9	78·6	78·9	79·4	79·9	80·5	80·7
Diurnal variation ...	.....	.....	.....	0·7	0·6	0·5	0·3	0·0	0·3	0·8	1·3	1·9	2·1

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Table E.

made during the Month of January, 1849.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.
Standard Thermometer.	87·5	86·3	86·5	85·0	83·7	81·7	80·3	79·5	79·1	.....	.....	1551·2	81·7
	12·0	10·8	11·0	9·5	8·2	6·2	4·8	4·0	3·6				

made during the Month of January, 1849.

Standard Thermometer.	94·7	92·7	90·9	87·1	83·8	80·9	79·2	78·4	77·9	.....	.....	1570·5	82·6
	20·6	18·6	16·8	13·0	9·7	6·8	5·1	4·3	3·8				

made during the Month of June, 1846.

Standard Thermometer.	84·6	84·6	84·2	83·5	82·6	81·2	79·9	79·2	78·6	78·2	77·8	1909·8	79·6
	8·7	8·7	8·3	7·6	6·7	5·3	4·0	3·3	2·7	2·3	1·9		

made during the Month of July, 1846.

Standard Thermometer.	83·1	83·5	83·2	82·9	82·0	81·0	79·2	78·6	78·1	77·7	77·3	1892·1	78·8
	7·8	8·2	7·9	7·6	6·7	5·7	3·9	3·3	2·8	2·4	2·0		

made during the Month of August, 1846.

Standard Thermometer.	84·2	84·5	84·3	82·8	82·0	80·8	78·7	77·9	77·6	77·3	77·0	1889·6	78·7
	9·3	9·6	9·4	7·9	7·1	5·9	3·8	3·0	2·7	2·4	2·1		

made during the Month of June, 1848.

Standard Thermometer.	88·7	86·7	85·4	84·5	82·7	81·2	79·6	78·7	77·9	.....	.....	1550·8	81·5
	15·3	13·3	12·0	11·1	9·3	7·8	6·2	5·3	4·5				

made during the Month of January, 1846.

Standard Thermometer.	90·2	86·1	83·6	82·8	80·4	78·9	78·4	78·7	77·9	.....	.....	1463·5	81·5
	15·0	10·9	8·4	7·6	5·2	3·7	3·2	3·5	2·7				

made during the Month of November, 1848.

Standard Thermometer.	80·9	80·9	80·8	80·5	80·4	80·3	80·1	79·9	79·5	.....	.....	1517·8	79·9
	2·3	2·3	2·2	1·9	1·8	1·7	1·5	1·3	0·9				

Table E.

Observatory at Singapore.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Standard Thermometer.													
Mean of 14 days ...	.....	.....	.....	79·0	78·9	78·7	78·2	78·0	78·5	79·4	80·0	80·3	80·7
Diurnal variation ...	.....	.....	.....	1·0	0·9	0·7	0·2	0·0	0·5	1·4	2·0	2·3	2·7

Observatory at Carimon Island.—Hourly observations

Standard Thermometer.													
Mean of 6 days	.....	.....	.....	.....	.....	76·7	76·4	78·6	81·7	85·0	87·2	90·3	90·8
Diurnal variation ...	.....	.....	.....	.....	.....	0·3	0·0	2·3	5·3	8·6	10·8	13·9	14·4

Observatory at Padang.—Hourly observations

Standard Thermometer.													
Mean of 13 days ...	.....	.....	.....	73·0	72·8	72·6	72·4	74·1	78·2	82·6	85·3	87·3	88·7
Diurnal variation ...	.....	.....	.....	0·6	0·4	0·2	0·0	1·7	5·8	10·2	12·9	14·9	16·3

Observatory at Padang.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	.....	.....	.....	73·4	73·2	73·0	73·0	74·5	78·5	82·9	85·3	87·5	88·8
Diurnal variation ...	.....	.....	.....	0·4	0·2	0·0	0·0	1·5	5·5	9·9	12·3	14·5	15·8

Observatory at Padang.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	.....	.....	.....	74·0	73·5	73·3	73·2	74·1	77·8	82·7	86·2	88·6	90·8
Diurnal variation ...	.....	.....	.....	0·8	0·3	0·7	0·0	0·9	4·6	9·5	13·0	15·4	17·6

Observatory at Padang.—Hourly observations

Standard Thermometer.													
Mean of 13 days ...	.....	.....	.....	73·8	73·5	73·3	73·2	73·9	77·7	82·6	85·7	88·6	89·9
Diurnal variation ...	.....	.....	.....	0·6	0·3	0·1	0·0	0·7	4·5	9·4	12·5	15·4	16·7

Observatory at Poolo Bay.—Hourly observations

Standard Thermometer.													
Mean of 5 days ...	.....	.....	.....	73·7	73·4	73·3	73·2	75·2	78·1	80·9	83·4	84·2	85·6
Diurnal variation ...	.....	.....	.....	0·5	0·2	0·1	0·0	2·0	4·9	7·7	10·2	11·0	12·4

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 19 days ...	77·7	77·4	76·9	76·6	76·3	76·0	75·7	76·5	78·7	80·9	83·1	84·9	85·8
Diurnal variation ...	2·0	1·7	1·2	0·9	0·6	0·3	0·0	0·8	3·0	5·2	7·4	9·2	10·1

TABLE E.

made during the Month of December, 1848.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.
Standard Thermometer.	80·8	80·6	80·7	80·6	80·1	79·8	79·8	79·7	79·4	.....	.....	1513·2	79·6
	2·8	2·6	2·7	2·6	2·1	1·8	1·8	1·7	1·4				

made during the Month of January, 1846.

Standard Thermometer.	90·8	91·4	89·5	88·2	85·7	82·2	80·7	79·7	.....	.....	.....	1354·9	84·8
	14·4	15·0	13·1	11·8	9·3	5·8	4·3	3·3					

made during the Month of October, 1847.

Standard Thermometer.	88·9	88·5	87·2	84·9	82·1	79·7	77·9	76·4	75·6	.....	.....	1528·2	80·5
	16·5	16·1	14·8	12·5	9·7	7·3	5·5	4·0	3·2				

made during the Month of November, 1847.

Standard Thermometer.	89·4	88·4	86·9	85·0	82·9	80·2	78·5	77·2	76·3	.....	.....	1534·9	80·8
	16·4	15·4	13·9	12·0	9·9	7·2	5·5	4·2	3·3				

made during the Month of December, 1847.

Standard Thermometer.	91·5	90·6	88·9	85·7	83·3	80·3	78·2	77·0	75·9	.....	.....	1545·6	81·3
	18·3	17·4	15·7	12·5	10·1	7·1	5·0	3·8	2·7				

made during the Month of January, 1848.

Standard Thermometer.	92·1	91·5	89·5	87·5	84·8	81·3	79·0	77·4	76·5	.....	.....	1551·8	81·7
	18·9	18·3	16·3	14·3	11·6	8·1	5·8	4·2	3·3				

made during the Months of August and September, 1847.

Standard Thermometer.	85·0	83·2	82·1	82·2	81·0	79·3	78·1	76·5	75·8	.....	.....	1504·2	79·3
	11·8	10·0	8·9	9·0	7·8	6·1	4·9	3·3	2·6				

made during the Month of November, 1846.

Standard Thermometer.	86·0	86·0	85·2	84·2	83·0	81·3	80·4	79·7	79·1	78·7	78·3	1928·4	80·3
	10·3	10·3	9·5	8·5	7·3	5·6	4·7	4·0	3·4	3·0	2·6		

Table E.

Observatory at Batavia.—Hourly observations

Astron. Mean Time of Station.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	0.
Standard Thermometer.													
Mean of 26 days ...	77·3	77·1	76·8	76·4	76·1	75·9	75·7	76·3	78·3	80·9	83·2	84·4	84·2
Diurnal variation ...	1·6	1·4	1·1	0·7	0·4	0·2	0·0	0·6	2·6	5·2	7·5	8·7	8·5

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 25 days ...	78·1	77·7	77·0	76·4	76·0	75·6	75·4	75·8	77·2	79·4	80·9	82·2	83·3
Diurnal variation ...	2·7	2·3	1·6	1·0	0·6	0·2	0·0	0·4	1·8	4·0	5·5	6·8	7·9

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 24 days ...	77·5	77·3	77·0	76·6	76·4	76·2	76·1	76·3	77·3	79·1	80·6	82·0	83·2
Diurnal variation ...	1·4	1·2	0·9	0·5	0·3	0·1	0·0	0·2	1·2	3·0	4·5	5·9	7·1

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 27 days ...	.....	.....	.....	77·8	77·4	77·0	76·7	77·0	78·3	80·4	82·2	83·6	84·4
Diurnal variation ...	.....	.....	.....	1·1	0·7	0·3	0·0	0·3	1·6	3·7	5·5	6·9	7·7

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	.....	.....	.....	77·3	76·7	76·2	76·1	76·7	78·6	81·0	83·1	84·4	85·3
Diurnal variation ...	.....	.....	.....	1·2	0·6	0·1	0·0	0·6	2·5	4·9	7·0	8·3	9·2

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	.....	.....	.....	76·3	75·8	75·3	75·1	75·9	78·3	82·2	83·6	85·3	86·7
Diurnal variation ...	.....	.....	.....	1·2	0·7	0·2	0·0	0·8	3·2	7·1	8·5	10·2	11·6

Observatory at Batavia.—Hourly observations

Standard Thermometer.													
Mean of 26 days ...	.....	.....	.....	75·5	75·1	74·7	74·4	75·1	77·4	81·2	83·5	85·2	86·4
Diurnal variation ...	.....	.....	.....	1·1	0·7	0·3	0·0	0·7	3·0	6·8	9·1	10·8	12·0

Observatory at Cocos Island.—Hourly observations

Standard Thermometer.													
Mean of 27 days ...	.....	.....	.....	76·9	76·7	76·8	76·6	77·0	78·1	80·0	81·4	83·0	83·4
Diurnal variation ...	.....	.....	.....	0·3	0·1	0·2	0·0	0·4	1·5	3·4	4·8	6·4	6·8

Table E.

made during the Month of December, 1846.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Sums.	Means.
Standard Thermometer.												
84·8 9·1	84·7 9·0	84·3 8·6	83·7 8·0	82·1 6·4	80·5 4·8	79·7 4·0	79·2 3·5	78·6 2·9	78·2 2·5	77·7 2·0	1916·1	79·8

made during the Month of January, 1847.

Standard Thermometer.												
84·4 9·0	84·7 9·3	84·8 9·4	84·4 9·0	83·8 8·4	82·4 7·0	81·0 5·6	80·4 5·0	80·0 4·6	79·4 4·0	78·8 3·4	1919·1	80·1

made during the Month of February, 1847.

Standard Thermometer.												
83·9 7·8	84·2 8·1	83·7 7·6	82·8 6·7	81·8 5·7	80·7 4·6	80·1 4·0	79·3 3·2	79·0 2·9	78·7 2·6	78·3 2·2	1908·1	79·6

made during the Month of March, 1847.

Standard Thermometer.												
85·0 8·3	85·4 8·7	85·6 8·9	85·0 8·3	84·1 7·4	82·4 5·7	81·5 4·8	80·9 4·2	80·0 3·3	.....	.....	1544·7	81·3

made during the Month of April, 1847.

Standard Thermometer.												
85·5 9·4	85·5 9·4	85·3 9·2	84·7 8·6	83·5 7·4	82·4 6·3	81·4 5·3	80·5 4·4	79·8 3·7	.....	.....	1544·0	81·3

made during the month of May, 1847.

Standard Thermometer.												
86·5 11·4	85·8 10·7	85·5 10·4	84·9 9·8	83·8 8·7	82·0 6·9	81·0 5·9	80·2 5·1	79·5 4·4	.....	.....	1543·7	81·2

made during the Month of June, 1847.

Standard Thermometer.												
86·7 12·3	86·4 12·0	86·2 11·8	84·9 10·5	83·7 9·3	81·9 7·5	80·9 6·5	80·0 5·6	79·6 5·2	.....	.....	1538·8	81·0

made during the Months of August and September, 1848.

Standard Thermometer.												
83·4 6·8	82·4 5·8	81·3 4·7	80·1 3·5	79·0 2·4	78·1 1·5	77·8 1·2	77·6 1·0	77·5 0·9	.....	.....	1507·1	79·2

TABLE F.

Observations of Inclination at various Stations in the Eastern Archipelago.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				—	—	—	South.
1846.							
Mar. 18.	Singapore	Madras.	A 1.	8 48·6	16 53·1	12 50·9	—
19.			A 1.	8 54·8	16 28·3	12 41·6	
21.			A 1.	8 48·7	16 48·3	12 48·5	
21.			A 1.	8 37	16 38·1	12 37·5	
27.			A 1.	8 16·3	16 58·9	12 37·6	
Apr. 16.			A 1.	8 54·1	16 48·2	12 51·1	
17.			A 1.	9 03·0	16 40·5	12 51·8	
21.			A 1.	8 50·7	16 51·9	12 51·3	
				Mean dip from A 1.....			12 44·6
Mar. 17.			A 2.	11 13·0	14 36·3	12 54·7	
19.			A 2.	11 31·5	14 13·4	12 52·4	
21.			A 2.	11 28·5	13 51·2	12 39·8	
21.			A 2.	11 31·6	14 16·8	12 54·3	
27.			A 2.	11 19·3	14 08·1	12 44·1	
28.			A 2.	11 03·9	14 13·6	12 38·3	
Apr. 16.			A 2.	10 40·2	13 42·7	12 41·5	
17.			A 2.	11 28·2	14 20·8	12 54·6	
21.			A 2.	11 36·1	13 54·8	12 45·4	
				Mean dip found from A 2			12 47·2
Mar. 21.			A 2 L.	12 29·5	13 06·4	12 48·0	
Apr. 16.			A 2 L.	12 19·4	13 10·5	12 44·9	
17.			A 2 L.	12 04·9	13 47·4	12 56·2	
21.			A 2 L.	12 22·3	13 29·8	12 56·1	
				Mean dip from A 2 L....			12 51·3
				—	+		
Mar. 21.			A 1 L.	25 13·9	0 24·5	12 36·9	
Apr. 16.			A 1 L.	24 56·7	0 12·1	12 22·3	
17.			A 1 L.	24 52·6	0 29·1	12 11·7	
21.			A 1 L.	24 49·7	0 39·4	12 05·1	
				Mean dip from A 1 L.....			12 19·0
				Add for correction			— 28·0
				Mean dip with correction...			12 47
				Mean dip found at Singapore.....			12 47
	BORNEO.						
May 15.	Sarāwak	Madras.	A 1.	7 10·3	14 51	11 00·1	
21.			A 1.	7 19·1	14 51·8	11 05·5	
27.			A 1.	7 25·0	15 13·4	11 19·2	
29.			A 1.	7 21	15 01·7	11 11·3	
June 13.			A 1.	7 12·7	15 09·1	11 11·0	
20.			A 1.	7 21·5	15 06·3	11 13·9	
27.			A 1.	7 12·5	15 04·3	11 08·4	
July 2.			A 1.	7 11·2	14 50·0	11 00·6	
6.			A 1.	7 00·7	15 17·4	11 09·0	
				Mean dip at Sarawak from A 1.....			11 08·8
May 15.			A 2.	9 29·3	12 21·6	10 55·5	
21.			A 2.	9 51·5	12 35·8	11 13·7	
27.			A 2.	9 52·0	12 32·3	11 12·5	
29.			A 2.	9 58·5	12 31·4	11 15·0	
June 13.			A 2.	10 03	12 44·2	11 23·6	
20.			A 2.	9 58·3	12 28·0	11 13·2	
27.			A 2.	9 27·8	13 10·3	11 19·1	
July 2.			A 2.	9 37·3	12 36·0	11 06·9	
6.			A 2.	9 42	12 29·2	11 05·6	
				Mean dip from A 2.....			11 11·6
May 15.			A 2 L.	10 40·8	11 47·1	11 14	
21.			A 2 L.	10 20·6	12 17·3	11 18·9	
27.			A 2 L.	10 01·5	11 58·5	10 59·0	
29.			A 2 L.	10 00·5	11 54·6	10 57·5	
June 13.			A 2 L.	10 11·8	12 11·5	11 11·6	
20.			A 2 L.	10 19·4	12 15·9	11 17·6	
27.			A 2 L.	10 16·1	11 48·1	11 02·1	
July 2.			A 2 L.	10 08·5	12 01·3	11 04·9	
6.			A 2 L.	10 37·6	11 49·9	11 13·7	
				Mean dip from A 2 L....			11 08·8

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				° ′	° ′	° ′	South.
1846.	BORNEO.						
May 15.	Sarāwak	Madras.	A 1 L.	23 23·6	1 42	10 50·8	
21.			A 1 L.	23 31·3	1 49·2	10 51·1	
27.			A 1 L.	23 36·2	1 59·1	10 48·5	
29.			A 1 L.	23 29·7	2 19·8	10 31·4	
June 13.			A 1 L.	23 25·7	1 44·6	10 50·5	
			A 1 L.	20 14·2	1 28	10 59·1*	
20.			A 1 L.	20 43·1	1 19	11 00·1	
27.			A 1 L.	20 37·5	1 06	10 51·7	
July 2.			A 1 L.	20 37·5	0 54·5	10 44·6	
6.							
				Mean from A 1 L.		10 49·7	
				Add for correction		— 28·0	
				Mean dip from A 1 L.....		.....	11 17·7
				Mean dip found at Sarāwak			11 10·9
July 20.	Sambas		A 1.	7 21·2	15 15·7	11 18·3	
				7 29·1	15 21·5	11 25·3	
				Mean dip at Sambas from A 1			11 21·8
			A 2.	10 17·4	12 47	11 32·2	
				10 04·3	12 38·4	11 21·4	
				Mean dip at Sambas from A 2			11 26·8
			A 2 L.	10 37·4	12 31·5	11 34·5	
				10 37·1	12 17·7	11 27·5	
				Mean dip at Sambas from A 2 L. ...			11 31
			A 1 L.	20 43·8	1 09·7	10 56·8	
				20 47·3	1 25·9	11 06·6	
				Mean dip from A 1 L.....		11 01·7	
				Add for cor.— 28		28	
				Mean dip from A 1 L.			11 29·7
				Mean dip found at Sambas			11 27
July 26.	Permanket		A 1.	8 41·0	16 18	12 29·5	
			A 2.	11 08·7	13 47·3	12 28·0	
			A 2 L.	11 47·5	13 21·3	12 34·4	
			A 1 L.	21 43·6	2 37·8	12 38·7†	
				Mean dip at Permanket			12 31·8
Aug. 3.	Pantiānak		A 1.	10 57·6	18 28·5	14 43·0	
			A 1.	10 41·2	18 29·5	14 35·4	
			A 1.	10 51·2	18 35·4	14 43·3	
				Mean dip from A 1.....			14 40·6
			A 2.	13 27·8	15 55·5	14 41·7	
			A 2.	13 12·6	16 16·4	14 44·5	
			A 2.	13 05·1	16 04·7	14 35·0	
				Mean dip from A2		14 40·4	14 40·4
			A 2 L.	13 52·3	15 47·1	14 49·7	
			A 2 L.	13 48	15 29·0	14 38·5	
			A 2 L.	14 04·7	15 27·2	14 46·1	
				Mean dip from A 2 L.....			14 44·7
			A 1 L.	23 57·7	4 45·1	14 21·4	
			A 1 L.	23 35·0	4 36·8	14 05·9	
			A 1 L.	23 30·3	4 34·4	14 09·4	
				Mean dip from A 1 L.....		14 09·9	
				Add for correction		— 28	
				Mean dip from A 1 L.....		.....	14 37·9
				Mean dip found at Pantiānak in Borneo.....			14 41·3

* Grinding the needle slightly on a hone.
† Correction —28′ for A 1 L.

Table F.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
1846.	BORNEO.			—	—	—	South. —
Aug. 13.	Succadāna		A 1.	18 06·1	26 47·4	16 57·8	
			A 2.	15 30·8	18 35·2	17 03·0	
			A 2 L.	16 22·7	17 45·2	17 03·9	
			A 1 L.	25 44·2	6 58·6	16 49·4*	
			Mean dip at Succadāna...			16 58·4	
	JAVA.						
Sept. 14.	Batavia		A 1.	23 46·4	30 26·4	27 06·4	
				24 03·7	30 19·5	27 11·6	
				23 51·7	30 07·6	26 59·6	
			Mean dip from A 1.			27 05·7	
			A 2.	25 51·3	28 22·2	27 06·7	
				25 47·3	28 09·0	26 58·1	
				25 51·1	28 21·3	27 06·2	
			Mean dip from A 2.			27 03·7	
			A 2 L.	26 25·9	27 44·7	27 05·3	
				26 17	27 44·7	27 00·8	
				26 15·7	27 41·2	26 58·2	
			Mean dip from A 2 L. ...			27 01·5	
		Madras.	A 1 L.	34 46·6	18 00·6	26 23·6	
				34 49·5	17 51·7	26 20·6	
				34 56·6	18 34·8	26 45·7	
			Mean dip from A 1 L.			26 30	
			Add for correction			28	
			Mean dip corrected for A 1 L.			26 58	
			Mean dip at Batavia			27 03·0	
Sept. 29.	Bantam Residency, Ceram.		A 1.	23 55·9	30 19·7	27 07·8	
			A 2.	26 07·3	28 26·2	27 16·7	
			A 2 L.	26 39·8	27 39·2	27 09·5	
			A 1 L.	34 57·3	18 25·0	27 09·1*	
			Mean dip at Ceram			27 11·0	
	Anjeer		A 1.	23 12·6	30 00	26 36·3	
			A 2.	25 17·4	27 30	26 23·7	
			A 2 L.	25 48·5	27 11·4	26 30	
			A 1 L.	34 11·6	17 35·1	26 21·3*	
			Mean dip at Anjeer			26 28·8	
Oct. 2.	Cheringin		A 1.	24 24·0	30 37·8	27 30·9	
			A 2.	28 33·2	26 23·6	27 28·4	
			A 2 L.	26 56·7	18 16·1	27 36·4	
			A 1 L.	35 05·8	18 47·0	27 24·4*	
			Mean dip at Cheringin...			27 30·8	
	5. Palambangan		A 1.	25 01·4	31 19·3	28 10·3	
			A 2.	26 44	29 18·6	28 01·3	
			A 2 L.	27 25·6	28 47·3	28 06·4	
			A 1 L.	35 46·8	19 21·2	28 02*	
			Mean dip at Palambangan			28 05·4	
	7. Chebiliang ...	Madras.	A 1.	25 27·8	32 02·5	28 45·1	
			A 2.	27 26·2	29 43·1	28 34·6	
			A 2 L.	27 56·4	29 20·7	28 33·3	
			A 1 L.	36 17·7	19 42·4	28 28*	
			Mean dip at Chebiliang...			28 37·9	
	9. Chelangkahan		A 1.	25 01·8	31 38·1	28 20	
			A 2.	27 02·8	29 27·6	28 15·2	
			A 2 L.	27 44·7	29 03·8	28 24	
			A 1 L.	36 04·8	19 53·4	28 26·8*	
			Mean dip at Chelangkahan			28 20·7	
	12. Goonong Dādap.		A 1.	24 23·9	30 38·2	27 31	
			A 2.	26 12·5	28 36·9	27 24·7	
			A 1 L.	35 00	19 06·6	27 31*	
			Mean dip at Goonong Dadap			27 28·5	
	14. Woorong Goonong.		A 1.	24 12·5	30 39·9	27 26·2	
			A 2.	26 10	28 02	27 06·0	
			A 2 L.	26 43·5	28 04·8	27 24·1	
			A 1 L.	35 10·1	18 47·4	27 26·7*	
			Mean dip at Woorong Goonong			27 20·0	
	23. Tanāra		A 1.	33 43·3	30 22·2	27 02·7	
			A 2.	25 47·3	28 12·7	27 00·0	
			A 2 L.	28 16·0	26 11·1	27 13·5	
			A 1 L.	34 44·0	18 02	26 51*	
			Mean dip at Tanāra			27 02·6	

* Correction −28′ for A 1 L.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
1846.	JAVA.			—	—	—	South. —
Nov. 9.	Batavia		A 1.	25 49·1	30 24·1	27 06·6	
			A 2.	25 39·4	28 25·5	27 02·5	
			A 2 L.	26 20·3	27 34·3	26 57·3	
			A 1 L.	34 51·4	18 04·2	26 55·8*	
			Mean of the four needles			27 00·5	
12.		Madras.	A 1.	23 45·1	30 11·1	26 58·1	
			A 2.	25 24·7	28 28·7	26 56·7	
			A 2 L.	26 01·4	27 28·1	26 44·7	
			A 1 L.	34 33·4	18 23·9	26 56·6*	
			Mean of the four needles			26 54·0	
			Mean dip at Batavia			26 57·2	
14.		2	A 1.	27 26·4	26 44·5	27 05·4	
		2	A 2.	26 25·9	27 35·4	27 00·3	
		1	A 1.	27 00·0	27 04·2	27 02·1	
		1	A 2.	27 11·0	26 54·1	27 02·6	
		3	A 1.	27 08·7	26 47·8	26 58·2	
		3	A 2.	27 00·7	27 10·9	27 05·8	
			General mean found at Batavia by the new needles			27 02·4	
Nov. 21.	Tegu	2	A 1.	29 05·0	28 24·7	28 44·8	
		2	A 2.	29 03	28 18·5	28 40·7	
		2	A 1 L.	28 53·7	28 40·0	28 46·8	
		2	A 2 L.	28 50·0	28 35·2	28 42·6	
		2	A 1.	29 00·6	28 20·2	28 40·4	
		2	A 2.	28 16·2	29 18·2	28 47·2	
		2	A 1 L.	28 51·0	28 33·6	28 42·3	
		2	A 2 L.	28 50·4	28 35·1	28 42·8	
	23.	1	A 1.	28 37·7	28 55·1	28 46·4	
		1	A 2.	28 42·1	28 37·4	28 39·8	
		1	A 1 L.	28 56·5	28 30·5	28 43·5	
		1	A 2 L.	28 38·4	28 46·2	28 42·3	
		1	A 1.	28 38·8	28 38·7	28 38·8	
		1	A 2.	28 43·6	28 32·4	28 38	
		1	A 1 L.	28 53·8	28 30·5	28 42·2	
		1	A 2 L.	28 34·8	28 44·4	28 39·6	
		3	A 1.	29 02·0	28 21·1	28 41·5	
		3	A 2.	28 39·5	28 51·2	28 45·3	
		3	A 1 L.	28 50·5	28 36·5	28 43·5	
	26. Pangerango, top of the mountain, Gedē.	3	A 2 L.	28 33·9	28 45·0	28 39·4	28 42·5
		2	A 1.	29 54·9	29 36·7	29 45·8	
		2	A 1 L.	29 48·1	29 37·5	29 42·8	
		2	A 2 L.	29 54·7	29 32·8	29 43·8	
		1	A 1 L.	29 54·1	29 31·0	29 42·5	
		1	A 2 L.	29 33·4	29 44·1	29 38·7	29 42·7
	30. Chunjūr	2	A 1.	28 46·7	28 08·6	28 27·6	
		2	A 2.	28 54·2	28 01·5	28 27·8	
		2	A 1 L.	28 35·0	28 20·0	28 27·5	
		2	A 2 L.	28 34·8	28 17·7	28 26·2	
		1	A 1.	28 20·5	28 19·0	28 20·0	
		1	A 2.	28 19·2	28 19·5	28 19·5	
		1	A 1 L.	28 34·5	28 13·2	28 23·9	
		1	A 2 L.	28 17·5	28 24·5	28 20·8	
		3	A 1.	28 31·2	28 05·4	28 18·2	
		3	A 2.	28 21·7	28 26·2	28 24·0	
		3	A 1 L.	28 22·5	28 15·0	28 20·0	
		3	A 2 L.	28 14·1	28 29·9	28 22	28 23·1
Dec. 4.	Kārang Tengga	2	A 1.	28 42·7	28 06·2	28 24·5	
			A 2.	28 53·1	27 52·1	28 22·4	
			A 1 L.	28 25·8	28 07·6	28 16·7	
			A 2 L.	28 28·4	28 11·2	28 19·8	28 21·1
	7. Chebrānok ...	2	A 1.	28 45·2	28 07·8	28 26·5	
			A 2.	28 56·6	28 00·0	28 28·3	
			A 1 L.	28 36·1	28 21·4	28 28·7	28 27·8
	8. Palabuan Rātoo, or Wine Cooper's Bay.	2	A 1.	29 36·5	28 59·5	29 18·0	
			A 2.	29 44·1	28 52·7	29 18·4	
			A 1 L.	29 25·9	29 13·9	29 19·9	
			A 2 L.	29 24·7	29 10·5	29 17·6	29 18·5

* Correction −28′ for A 1 L.

TABLE F.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				—	—	—	South.
1846.	JAVA.						—
Dec. 10.	Chilotoe	2	A 1.	29 08·7	28 33·0	28 50·9	
			A 2.	29 17·7	28 21·4	28 49·5	
			A 1 L.	28 58·5	28 48·2	28 53·4	
			A 2 L.	29 10·4	28 32·7	28 51·5	28 51·3
11.	Pangangbahan	2	A 1.	29 58·1	29 20·1	29 39·0	
			A 2.	30 10·2	29 13·8	29 42·0	
			A 1 L.	29 46·5	29 35·9	29 41·2	
			A 2 L.	29 46·8	29 40·4	29 43·6	29 41·4
13.	Mooāro Chikasso.	2	A 1.	30 14·9	29 48·3	30 06·6	
			A 2.	30 30·1	29 39·5	30 04·8	
			A 1 L.	30 11·9	29 57·6	30 04·8	
			A 2 L.	30 12·7	29 57·4	30 05·0	30 05·3
14.	Sidang Bārang	2	A 1.	31 07·0	29 15·3	30 11·1	
			A 2.	30 38·5	29 42·7	30 10·6	
			A 1 L.	30 24·9	30 07·9	30 16·4	
			A 2 L.	30 19·9	30 03·6	30 11·7	
15.		2	A 1.	31 05·8	29 17·2	30 11·5	
			A 2.	30 41·0	29 41·8	30 11·4	
			A 1 L.	30 19·2	30 06·6	30 12·9	
			A 2 L.	30 19·2	30 02·0	30 10·6	30 12·0
16.	Bejong Petair	2	A 1.	30 25·5	28 35·0	29 30·3	
			A 2.	30 00·3	29 04·6	29 32·5	
			A 1 L.	29 42·0	29 28·3	29 35·2	
			A 2 L.	29 41·4	29 23·5	29 32·5	29 33·5
21.	Bandong	2	A 1.	29 24·9	27 30·1	28 27·5	
			A 2.	28 56·1	27 59·3	28 27·7	
			A 1 L.	28 35·2	28 24·8	28 30·0	
			A 2 L.	28 38·5	28 13·2	28 25·8	28 28·0
		2	A 1.	29 34·4	27 36·5	28 35·5	
			A 2.	29 02·8	28 09·8	28 36·3	
			A 1 L.	28 38·8	28 29·7	28 34·2	
			A 2 L.	28 46·2	28 25·8	28 36·0	
		1	A 1.	28 22·5	28 28·9	28 25·7	
			A 2.	28 27·1	28 24·2	28 25·7	
			A 1 L.	28 43·6	28 28·1	28 27·9	
			A 2 L.	28 31·5	28 29·2	28 29·2	
21.		3	A 1.	28 53·0	28 18·0	28 35·5	
			A 1 L.	28 39·8	28 34·1	28 36·9	
			A 1 L.	28 26·0	28 38·4	28 32·2	28 31·4
24.	Garoet	2	A 1.	29 54·1	28 03·5	28 58·8	
			A 2.	29 24·5	28 34·0	28 59·2	
			A 1 L.	29 07·4	28 51·6	28 59·5	
			A 2 L.	29 06·5	28 51·4	28 59·0	
		1	A 1.	28 55·7	28 57·9	28 56·8	
			A 2.	28 54·3	29 01·5	28 57·9	28 58·5
28.	Permangpek.	2	A 1.	31 05·6	29 15·3	30 10·5	
			A 2.	30 37·4	29 43·8	30 10·6	
			A 1 L.	30 16·0	30 05·2	30 10·6	
			A 2 L.	30 20·3	30 02·6	30 11·4	
29.		2	A 1.	31 07·4	29 18·6	30 13·0	
			A 2.	30 39·4	29 46·7	30 13·1	
			A 1 L.	30 18·7	30 05·6	30 12·1	
			A 2 L.	30 22·7	30 05·4	30 14·1	30 11·8
1847.							
Jan. 1.	Cherūngnūktok.	2	A 1.	31 03·7	29 13·7	30 08·4	
			A 2.	30 39·2	29 41·4	30 10·3	
			A 1 L.	30 09·1	30 01·7	30 07·9	
			A 2 L.	30 15·0	29 57·2	30 06·1	30 08·2
6.	Kālipoochen	2	A 1.	30 36·6	28 54·7	29 50·6	
			A 2.	30 21·4	29 20·8	29 51·1	
			A 1 L.	29 56·6	29 48·2	29 52·3	
			A 2 L.	29 59·4	29 42·4	29 49·9	29 51·2
8.	Banjeer	2	A 1.	30 03·5	28 10·2	29 06·7	
			A 2.	29 35·2	28 40·3	29 07·7	29 07·2
10.	Chāwee	2	A 1.	29 36·1	27 39·4	28 37·7	
			A 2.	29 06·6	28 14·2	28 40·4	
			A 1 L.	28 42·7	28 38·1	28 40·2	
			A 2 L.	28 46·6	28 30·2	28 38·4	28 39·2
12.	Samadang ...	2	A 1.	28 53·5	26 55·8	27 54·6	
			A 2.	28 26·5	27 28·9	27 57·2	
			A 1 L.	28 04·0	27 55·2	27 59·6	
			A 2 L.	28 07·2	27 50·2	27 58·7	27 57·5

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				—	—	—	South.
1847.	JAVA.						—
Jan. 15.	Cheribon	2	A 1.	28 47·1	28 49·2	27 48·1	
			A 2.	28 19·4	27 20·2	27 49·8	
			A 1 L.	27 54·5	27 47·1	27 50·7	
			A 2 L.	27 59·6	27 37·5	27 48·5	27 49·3
18.	Indramāyu ...	2	A 1.	28 32·8	26 27·0	27 29·5	
			A 2.	27 58·0	26 56·8	27 27·4	
			A 1 L.	27 30·6	27 28·2	27 29·4	
			A 2 L.	27 35·0	27 19·5	27 27·2	27 28·5
26.	Tegal	2	A 1.	28 55·7	27 01·6	27 58·6	
			A 2.	28 32·7	27 33·2	28 03·0	
			A 1 L.	28 09·3	27 59·3	28 04·3	
			A 2 L.	28 12·6	27 57·1	28 04·8	28 02·7
30.	Samārang ...	2	A 1.	28 57·6	27 02·5	28 00·0	
			A 2.	28 32·2	27 33·5	28 02·8	
			A 1 L.	28 07·4	27 57·6	28 02·5	
			A 2 L.	28 12·4	27 54·0	28 08·5	28 02·2
Feb. 2.	Japāra	2	A 1.	28 25·8	26 35·4	27 30·6	
			A 2.	27 55·8	27 02·5	27 29·1	
			A 1 L.	27 30·1	27 21·8	27 26·0	
			A 2 L.	27 32·1	27 16·8	27 24·5	27 27·5
5.	Ambarāwa ...	2	A 1.	30 18·7	28 27·0	29 22·8	
			A 2.	29 55·1	29 00·5	29 27·8	29 25·3
10.	Balembang ...	2	A 1.	29 56·1	28 01·0	28 58·5	
			A 2.	29 28·8	28 31·5	29 00·1	
			A 1 L.	28 55	29 06·5	29 00·7	
			A 2 L.	29 12·0	28 49·1	29 00·5	29 00·0
13.	Solo	2	A 1.	30 01·0	28 14·2	29 07·6	
			A 2.	29 37·4	28 43·8	29 10·6	
			A 1 L.	29 18·0	29 05·1	29 11·7	
			A 2 L.	29 21·8	29 01·3	29 11·5	29 10·3
18.	Nyāwee	2	A 1.	29 54·0	27 59·2	28 56·6	
			A 2.	29 31·2	28 34·6	29 02·9	
			A 1 L.	28 50·1	28 57·4	28 53·7	28 57·7
22.	Bankāwa, Solo River.	2	A 1.	28 42·4	26 49·4	27 45·9	
			A 2.	28 11·0	27 20·7	27 45·8	
			A 1 L.	28 53·1	27 45·1	27 49·1	
			A 2 L.	27 55·0	27 30·2	27 42·6	
			A 1 L.	27 46·7	27 38	27 42·3	27 45·1
25.	Soorabāya ...	2	A 1.	29 38·2	27 48·5	28 43·3	
			A 2.	29 18·8	28 20·0	28 49·4	
			A 1 L.	28 51·1	28 40·4	28 45·7	
			A 2 L.	28 53·5	28 53·8	28 53·6	
26.			A 1.	29 38·2	27 48·5	28 43·3	
			A 2.	29 21·9	28 29·2	28 55·5	
		2	A 1 L.	29 01·7	28 54·0	28 57·8	
			A 2 L.	28 57·6	28 48·2	28 52·9	28 50·8
Mar. 23.	Sūmcnap		A 1.	28 36	26 47·1	27 41·5	
			A 2.	28 05	27 17·5	27 41·2	
			A 1 L.	27 48·1	27 40·8	27 44·5	
			A 2 L.	27 49·3	27 39·4	27 44·4	
26.		...	A 1.	28 40·7	26 29·5	27 45·1	
			A 2.	28 14	27 19	27 46·5	
			A 1 L.	27 48·9	27 38·9	27 43·9	
			A 2 L.	27 48·4	27 39	27 43·9	
31.		...	*A 1.	28 37·2	26 27·3	27 42·2	
			A 2.	28 10·8	27 15	27 42·8	
			A 1 L.	27 49·1	27 43·9	27 46·0	
			A 2 L.	27 46	27 35	27 40·5	27 43·8
April 7.	Pulo Kuneeang.		A 1.	28 15·4	26 28·1	27 22·7	
			A 2.	27 40·7	26 55	27 17·8	
			A 1 L.	27 30	27 19·6	27 24·8	
8.			A 2 L.	27 27·3	27 14·5	27 20·9	
8.			A 1.	28 14·5	26 24·1	27 19·3	
			A 2.	27 45·5	26 53·7	27 19·6	
			A 1 L.	27 30·6	27 21·5	27 26	
			A 2 L.	27 36·8	27 19	27 27·9	
8.			A 1.	28 22·5	26 29·9	27 26·2	
			A 2.	27 54·6	26 57·9	27 26·2	
9.			A 1 L.	27 23·6	27 17·8	27 20·7	
			A 2 L.	27 29·3	27 11·2	27 19·2	27 23·6
26.	Bezooki		A 1.	29 57·5	28 10·4	29 03·9	
			A 2.	29 33·2	28 38·1	29 05·6	

TABLE F.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
1847.	JAVA.			—	—	—	South.
April 26.	Bezooki		A 1 L.	29 08·7	29 01·8	29 05·2	—
			A 2 L.	29 15·2	29 01·0	29 08·1	29 05·7
May 11.	Kedeeri		A 1.	30 42·8	28 49	29 45·9	
			A 2.	30 14·0	29 13·5	29 43·7	
			A 1 L.	29 55·5	29 47·2	29 51·2	
			A 2 L.	29 59·5	29 44·7	29 52·1	
12.			A 1.	30 42·6	28 53·6	29 48·1	
			A 2.	30 17·1	29 24·0	29 50·5	
			A 1 L.	29 55·9	29 46·8	29 51·3	
			A 2 L.	30 03·2	29 45·5	29 54·3	
13.			A 1.	30 42·8	28 51·4	29 47·1	
			A 2.	30 19·6	29 22·6	29 51·1	
			A 1 L.	29 54·3	29 49·3	29 51·8	
			A 2 L.	30 02·5	29 43·9	29 53·2	29 50·0
May 21.	Patchitan.....	2	A 1.	31 26·9	29 38·5	30 32·7	
			A 2.	31 03·1	30 06·5	30 34·8	
			A 1 L.	30 40·8	30 26·5	30 33·6	
			A 2 L.	30 45·1	30 29·1	30 37·1	30 34·5
June 1.	Munoori	2	A 1.	30 12·6	28 22·0	29 17·3	
			A 2.	29 46·2	28 52·4	29 19·2	
			A 1 L.	29 21·6	29 18·1	29 19·8	
			A 2 L.	29 27·5	29 11·8	29 19·6	29 19·0
6.	Kārang Bolong.	2	A 1.	30 45·7	28 58·5	29 52·1	
			A 2.	30 25	29 23·9	29 54·4	
			A 1 L.	29 58·3	29 53·5	29 55·9	
			A 2 L.	30 03·5	29 46·5	29 55·0	29 54·4
9.	Chilāchap ...	2	A 1.	30 39·3	28 46	29 42·6	
			A 2.	30 11·2	29 13·4	29 42·3	
			A 1 L.	29 48	29 47·5	29 47·5	
			A 2 L.	29 37·7	29 37·7	29 44·7	29 44·3
12.	Aji Bārang ...	2	A 1.	28 15·6	26 22·6	27 19·1	
			A 2.	27 42·3	26 54·5	27 18·4	
			A 1 L.	27 27·5	27 28·4	27 27·9	
			A 2 L.	27 27·8	27 13·8	27 21·5	27 20·8
July 6.	Batavia	2	A 1.	28 02	26 10·3	27 06·1	
			A 2.	27 31·5	26 34·5	27 03·0	
			A 1 L.	27 11·5	27 08·6	27 09·8	
			A 2 L.	27 15·6	26 57·1	27 06·3	
		2	A 1.	28 02·2	26 10·4	27 06·3	
			A 2.	27 31	26 35·0	27 03·4	
			A 1 L.	27 11·0	27 10·3	27 10·6	
			A 2 L.	27 21·8	27 00·8	27 11·3	
7.		2	A 1.	28 06·4	26 12·7	27 09·5	
			A 2.	27 31·3	26 38·5	27 04·9	
			A 1 L.	27 08·5	27 08·2	27 08·3	
			A 2 L.	27 17·5	26 56·1	27 06·6	
		2	A 1.	28 03·8	26 13·3	27 08·5	
			A 2.	27 29·9	26 41·7	27 05·8	
			A 1 L.	27 12·4	27 09·6	27 11·0	
			A 2 L.	27 20·9	26 58·9	27 09·9	
9.		2	A 1.	28 05·3	26 09·5	27 07·4	
			A 2.	27 15	26 39·5	27 03·5	
			A 1 L.	27 11·0	27 09·3	27 10·1	
			A 2 L.	27 19·6	26 59·8	27 09·7	
		2	A 1.	28 05·5	26 11·7	27 08·6	
			A 2.	27 28·3	26 38·5	27 03·4	
			A 1 L.	27 09·9	27 11·1	27 10·5	
			A 2 L.	27 16·1	26 58·5	27 07·3	
10.		1	A 1.	27 07·2	27 09·8	27 08·5	
			A 1 L.	27 03·4	27 23·0	27 13·2	
			A 2 L.	27 06·9	27 07·9	27 07·4	
		1	A 1.	27 11·5	27 06·0	27 08·7	
			A 1 L.	27 02·6	27 21·8	27 12·7	
			A 2 L.	27 06·0	27 09·6	27 07·8	
13.		1	A 1.	27 07·9	27 05·4	27 06·6	
			A 1 L.	27 00·5	27 20·0	27 10·2	
			A 2 L.	27 06·2	27 06·1	27 06·1	
14.		1	A 1.	27 06·5	27 04·5	27 05·5	
			A 1 L.	26 58·9	27 16·7	27 07·8	
			A 2 L.	27 03·2	27 06·4	27 04·8	
13.		3	A 2.	26 58·2	27 22·3	27 10·2	
			A 1 L.	27 23·5	27 00·7	27 12·5	

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
1847.	JAVA.			—	—	—	South.
July 14.	Batavia	3	A 2.	26 53·7	27 24	27 08·8	
			A 1 L.	27 21·1	26 58·3	27 09·7	
14.		3	A 2.	26 57·6	27 17·6	27 07·6	
			A 1 L.	27 20·3	27 03·9	27 12·1	
		3	A 2.	26 57·5	27 17·4	27 07·4	
			A 1 L.	27 22·4	27 00·2	27 11·3	27 08·2
17.		F.	B.	27 11·8	.....	27 11·8	
			B.	27 09·0	.....	27 09·0	
			B.	27 13·7	.....	27 13·7	
				27 17·6	.....	27 17·6	
19.			B.	27 12	.....	27 12	
				27 12·5	.....	27 12·5	
				25 59·6	28 05	27 02·3	
	SUMĀTRA.			26 01·7	28 07·3	27 04·5	27 09·3
Aug. 18.	Telok Betong, Lampong Bay.	2	A 1.	27 06·7	25 13·8	26 10·2	
			A 2.	26 42·6	25 44·4	26 13·5	
			A 1 L.	26 16·3	26 14·2	26 15·2	
			A 2 L.	26 24·9	26 06·3	26 15·6	26 14·8
Sept. 3.	Poolo Bay near Bencoolen.	2	A 1.	24 52·9	22 44	23 48·4	
			A 2.	24 22·7	23 22·1	23 52·4	
			A 1 L.	24 03·2	23 56·3	23 59·8	
			A 2 L.	24 02·2	23 42·6	23 52·4	
		1	A 1.	23 51·8	23 50·3	23 51·0	
			A 1 L.	23 59·4	23 56·2	23 57·8	
			A 2 L.	23 48·2	23 50·5	23 49·3	
		2	A 1.	24 49	22 49·3	23 49·1	
			A 2.	24 25·2	23 20·3	23 52·7	
			A 1 L.	24 03	23 52·0	23 57·5	
			A 2 L.	24 04·6	23 45	23 54·8	
4.		2	A 1.	24 54·8	22 51·2	23 53	
			A 2.	24 24·4	23 22·8	23 53·6	
			A 1 L.	23 55·6	23 53·9	23 53·7	
			A 2 L.	24 02·9	22 43·7	23 53·3	
		3	A 2.	23 43	24 04·4	23 53·7	
			A 1 L.	24 00·7	23 42·1	23 51·4	23 53·1
Oct. 18.	Padang	2	A 1.	19 33·8	17 20·7	18 27·2	
21.			A 2.	19 11·3	18 03·5	18 37·4	
			A 1 L.	18 37·5	18 36·8	18 37·4	
			A 2 L.	18 32	18 22·8	18 27·4	
23.		1	A 1.	18 26·2	18 25·7	18 26·0	
			A 1 L.	18 20·2	18 33·3	18 26·7	
			A 2 L.	18 22·8	18 31·1	18 26·9	
25.		3	A 2.	18 26	18 50·6	18 38·3	
			A 1 L.	18 46·7	18 29·3	18 38·0	18 31·7
				Poles Direct.			Cor. Dip.
		1	A 1, A 1 L.	18 36·4	18 40·6	18 38·5	
			A 1 L., A 2 L.	18 43·3	18 39·2	18 41·2	
			A 1, A 1 L.	18 31·9	18 41·4	18 36·6	
			A 1 L., A 2 L.	18 37·9	18 36·2	18 37·0	
			A 1, A 1 L.	18 38·2	18 48·1	18 43·1	
			A 1 L., A 2 L.	18 45·8	18 48·1	18 47	
Mean of the three needles with poles unchanged =						18 40·6	
And the true dip has been found to be ..... =						18 31·7	
Correction to be applied for the survey in Sumatra						+0 8·9	
Nov. 1.	Solok	1	A 1, A 1 L.	17 53·2	18 00·1	17 56·6	
			A 1 L., A 2 L.	17 54·3	18 01·5	17 57·9	
		1	A 1, A 1 L.	17 53	18 02·2	17 57·6	
			A 1 L., A 2 L.	18 01·7	17 57·8	17 59·7	
2.		1	A 1, A 1 L.	17 53·0	18 05·6	17 59·3	
			A 1 L., A 2 L.	18 03·7	18 05·1	18 04·4	17 50·3
5.	Sijonjong.....	1	A 1, A 1 L.	17 51·8	18 00·6	17 56·2	
			A 1 L., A 2 L.	18 03·8	17 56·7	18 00·2	17 49·3
8.	Bua Pārjāng .	1	A 1, A 1 L.	17 16·2	17 16·3	17 16·2	
			A 1 L., A 2 L.	17 19·9	17 23·2	17 21·5	17 10·9
10.	Pāyacombo ...	1	A 1, A 1 L.	16 41·9	16 47·5	16 44·7	
			A 1 L., A 2 L.	16 48·1	16 48·9	16 48·5	16 37·7

Table F.

Date.	Name of Station.	Circle.	Needle.	Poles direct.		Dip.	Corr. Dip.
				—	—	—	South.
1847.	SUMATRA.						—
Nov. 11.	Fort Vande Capellen.	1	A 1, A 1 L.	17 15·2	17 21·5	17 18·3	
			A 1 L., A 2 L.	17 19·7	17 26·7	17 23·2	17 11·8
14.	Padang Panjang.	1	A 1, A 1 L.	17 52·9	17 55·9	17 54·4	
			A 1 L., A 2 L.	17 54·8	18 00·3	17 57·5	17 47·0
16.	Fort de Kock.	1	A 1, A 1 L.	17 06·8	17 07·4	17 07·5	
			A 1 L., A 2 L.	17 08·6	17 10·5	17 09·5	16 59·4
17.	Menindjo ...	1	A 1 L., A 2 L.	17 03·6	17 10·1	17 07·4	
			A 1 L., A 2 L.	17 11·0	17 11·6	17 11·3	17 00·4
18.	Balembangan.	1	A 1, A 1 L.	16 48·0	16 58·2	16 53·5	
			A 1 L., A 2 L.	16 58·8	16 58·1	16 58·5	16 47·1
19.	Peesang	1	A 1, A 1 L.	16 38·0	16 43·1	16 40·5	
			A 1 L., A 2 L.	16 46·2	16 43·0	16 44·6	
		1	A 1, A 1 L.	16 36·8	16 43·1	16 39·9	
			A 1 L., A 2 L.	16 43	16 44·5	16 43·7	16 33·2
20.	Bonjol	1	A 1, A 1 L.	16 42·5	16 48·6	16 45·5	
			A 1 L., A 2 L.	16 48·6	16 49·2	16 48·9	16 38·3
21.	Loobisikapping.	1	A 1, A 1 L.	16 11·3	16 17·6	16 14·5	
			A 1 L., A 2 L.	16 17·8	16 21·2	16 19·5	16 08·1
22.	Batoo Bedindi	1	A 1, A 1 L.	15 59·7	16 00·2	15 55·4	
			A 1 L., A 2 L.	16 00·6	16 00·5	15 57·9	15 49
23.	Lender.....	1	A 1, A 1 L.	15 47·3	15 35·4	15 41·3	
			A 1 L., A 2 L.	15 43·7	15 49·6	15 46·6	15 35·0
24.	Rau	1	A 1, A 1 L.	15 37·9	15 49·8	15 43·8	
			A 1 L., A 2 L.	15 48·7	15 49 2	15 49·0	
25.		1	A 1, A 1 L.	15 35·5	15 48·4	15 41·9	
			A 1 L., A 2 L.	15 49·0	15 50·9	15 50·0	15 37·2
26.	Pionghay	1	A 1, A 1 L.	15 48·0	16 03·8	15 55·9	
			A 1 L., A 2 L.	16 02·0	16 02	16 02	15 50·0
27.	Batong.....	1	A 1, A 1 L.	15 40·9	15 54·5	15 47·7	
			A 1 L., A 2 L.	15 53·7	15 51·9	15 52·8	15 41·3
28.	Kotanopan ...	1	A 1, A 1 L.	15 18·3	15 33·1	15 25·7	
			A 1 L., A 2 L.	15 33·1	15 30·0	15 31·5	15 19·7
29.	Tana Batoo ...	1	A 1, A 1 L.	15 01·6	15 18·5	15 10·0	
			A 1 L., A 2 L.	15 14·7	15 12·7	15 13·7	15 02·9
Dec. 1.	Fort Elout ...	1	A 1, A 1 L.	14 44·5	15 01·7	14 53·1	
			A 1 L., A 2 L.	15 01·9	14 55·7	14 58·8	14 47·9
3.	Singalangan...	1	A 1, A 1 L.	14 11·5	14 24·2	14 17·8	
			A 1 L., A 2 L.	14 24·6	14 20·3	14 22·5	14 11·7
6.	Padang Sidompang.	1	A 1, A 2 L.	13 46·8	14 00·5	13 53·6	
			A 1 L., A 2 L.	14 00·4	13 55·3	13 57·9	13 46·8
11.	Sibogha	1	A 1, A 1 L.	13 03·2	13 14·2	13 08·6	
			A 1 L., A 2 L.	13 15·8	13 11·8	13 13·8	
13.		1	A 1, A 1 L.	13 04·8	13 19·0	13 11·9	
			A 1 L., A 2 L.	13 18·3	13 14·9	13 16·6	
15.		1	A 1, A 1 L.	13 06·0	13 18·2	13 12·1	
			A 1 L., A 2 L.	13 18·7	13 16·3	13 17·5	
16.		1	A 1, A 1 L.	13 04·3	13 19·8	13 12·0	
			A 1 L., A 2 L.	13 18·1	13 14·4	13 16·2	13 04·7
19.	Baros	1	A 1, A 1 L.	12 58	13 10·9	13 04·4	
			A 1 L., A 2 L.	13 06·8	13 06·5	13 06·6	
		1	A 1, A 1 L.	12 57	13 10·9	13 03·9	
			A 1 L., A 2 L.	13 11·8	13 03·8	13 07·8	
20.		1	A 1, A 1 L.	13 00·4	13 14·1	13 07·2	
			A 1 L., A 2 L.	13 13·4	13 07·8	13 10·6	12 57·8
23.	Sinkel	1	A 1, A 1 L.	12 24·3	12 35·5	12 29·9	
			A 1 L., A 2 L.	12 33·5	12 30·0	12 31·7	
25.		1	A 1, A 1 L.	12 26·1	12 36·0	12 31·0	
			A 1 L., A 2 L.	12 38·3	12 34·6	12 36·4	12 23·3
31.	Pulonias, Goonong Satoolie	1	A 1, A 1 L.	14 04·2	14 20·3	14 12·2	
			A 1 L., A 2 L.	14 19·2	14 14·4	14 16·9	14 05·6
1848.							
Jan. 10.	Natal	1	A 1, A 1 L.	15 30	15 39·1	15 34·5	
			A 1 L., A 2 L.	15 40·3	15 47·1	15 43·7	
11.		1	A 1, A 1 L.	15 34·5	15 48·4	15 41·5	
			A 1, A 1 L.	15 49·3	15 48·6	15 49	
12.		1	A 1 L., A 2 L.	15 31·0	15 44·2	15 37·6	
			A 1 L., A 2 L.	15 42·5	15 40·1	15 41·2	
13.		1	A 1, A 1 L.	15 29·3	15 46·4	15 37·8	15 32·2
			A 1 L., A 2 L.	15 45·4	15 42·7	15 44·0	

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				—	—	—	South.
1848.							—
Feb. 14.	Singapore ...	2	A 1.	1 01·9	1 46·5	1 54·2	
15.			A 2.	13 28·8	12 19·3	12 54·1	
			A 1 L.	12 59·0	12 51·9	12 55·4	
			A 2 L.	13 02·2	12 47·4	12 55·3	12 54·7
			A 1.	14 04·2	11 49·5	12 56·8	
			A 2.	13 34·7	12 19·1	12 56·9	
			A 1 L.	13 01·1	12 51·0	12 56·0	
			A 2 L.	13 05·8	12 45·6	12 55·7	12 56·3
			A 1.	14 04·6	11 57·3	13 00·9	
16.			A 2.	13 36·0	12 20·8	12 58·0	
19.			A 1 L.	13 01·6	12 33·3	12 57·4	
			A 2 L.	13 06·2	12 50·5	12 58·3	12 58·3
			A 1.	14 09·3	11 51·1	13 00·2	
			A 2.	13 29·8	12 22·3	12 56·0	
			A 1 L.	13 00·1	12 55·0	12 57·5	
			A 2 L.	13 07·5	12 52·0	12 59·7	12 58·2
21.		2	A 1.	14 10·4	11 54·6	13 02·5	
22.			A 2.	13 29·6	12 19·1	12 54·3	
			A 1 L.	13 05·0	13 00·1	13 02·5	
			A 2 L.	13 10·5	12 48·5	12 59·5	12 59·7
		2	A 1.	14 04·9	11 54·5	12 59·7	
			A 2.	13 31·3	12 26·3	12 58·8	
			A 1 L.	13 03·9	12 59·4	13 01·6	
			A 2 L.	13 07·1	12 52·5	12 59·8	13 00·0
22.		2	A 1.	14 09·2	11 43·7	12 56·4	
28.			A 2.	13 28·3	12 24·1	12 56·2	
			A 1 L.	13 09·4	12 57·4	13 03·4	
			A 2 L.	13 06·6	12 43·4	12 54·5	12 57·6
		2	A 1.	14 06·8	11 45·5	12 56·1	
			A 2.	13 31·8	12 21·5	12 56·6	
			A 1 L.	13 06·8	12 59·9	13 03·3	
			A 2 L.	13 06·7	12 42·5	12 54·6	12 57·6
24.		2	A 1.	14 04	11 48·6	12 56·3	
Mar. 1.			A 2.	13 29·7	12 16·3	12 53·0	
			A 1 L.	12 55·9	12 53·2	12 54·5	
			A 2 L.	13 02·6	12 43·1	12 52·7	12 54·1
		2	A 1.	14 07·3	11 45·0	12 56·1	
			A 2.	13 28·6	12 18·3	12 53·4	
			A 1 L.	13 03·2	13 00·7	13 02·0	
			A 2 L.	13 02·6	12 44·5	12 53·3	12 56·2
Feb. 26.		2	A 1.	14 04·3	11 44·5	12 54·4	
Mar. 3.			A 2.	13 29·3	12 20	12 54·6	
			A 1 L.	12 58·1	12 53·7	12 55·9	
			A 2 L.	13 06·1	12 41·7	12 53·9	12 54·7
		2	A 1.	14 04·7	11 46·9	12 55·8	
			A 2.	13 33·9	12 16·5	12 58·2	
			A 1 L.	13 00·3	12 55·5	12 57·9	
			A 2 L.	13 04·2	12 41·8	12 53·0	12 56·2
Feb. 23.		2	A 1.	14 04·0	11 46·7	12 55·3	
Mar. 1.			A 2.	13 28·3	12 14·7	12 51·6	
			A 1 L.	13 01·5	12 57·5	12 59·4	
			A 2 L.	13 05·7	12 45·8	12 55·7	12 55·5
			A 1.	14 04·8	11 46·6	12 55·7	
			A 2.	13 29·0	12 15·2	12 52·1	
			A 1 L.	13 02·0	12 58·7	13 00·3	
			A 2 L.	13 07·1	12 44·0	12 55·5	12 55·5
					Mean dip at Singapore...		12 56·8
28.	Mount Ophir, near Malacca.	2	A 1.	10 58·0	8 49·0	9 53·5	
			A 2.	10 27·7	9 18·3	9 53·0	
			A 1 L.	9 58·5	9 59·5	9 59·0	
			A 2 L.	10 10·3	9 45·6	9 57·9	9 55·8
May 3.	Pulo Labooan.	2	A 1.	3 55·0	1 45·3	2 50·1	
			A 2.	3 27·7	2 20·1	2 53·9	
			A 1 L.	3 01·6	2 53·0	2 57·3	
			A 2 L.	3 05·5	2 41·2	2 53·3	
4.		1	A 1.	2 54·3	2 54·2	2 54·2	
			A 1 L.	2 41·4	3 10	2 55·7	
			A 2 L.	2 43·2	2 54·9	2 49·0	
		3	A 2.	2 37·3	3 07·0	2 52·1	
			A 1 L.	3 07·2	2 38·6	2 52·9	2 53·1
5.							

TABLE F.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				+	+	+	North. +
1848.	MINDANÃO.						
May 25.	Sambooanga.	1	A 1 L.	1 35·8	1 07·3	1 21·5	
			A 2 L.	1 27·1	1 10·2	1 18·6	
			A 1.	1 19·7	1 17·6	1 18·6	
26.		3	A 2.	1 35·7	1 09·1	1 22·4	
			A 1 L.	2 08·2	1 37·4	1 22·8	
		2	A 1.	0 08·3	2 36·5	1 17·4	
			A 2.	0 39·8	1 57·0	1 18·4	
			A 1 L.	1 13·1	1 19·0	1 16·0	
			A 2 L.	1 06·9	1 28·3	1 17·6	1 19·3
	CELEBES.			—	—	—	South.
June 21.	Keemah	2	A 1.	12 07·0	10 00·8	11 03·9	—
			A 2.	11 40·3	10 28·8	11 04·5	
			A 1 L.	11 07·3	10 58·3	11 02·8	
			A 2 L.	11 14·0	10 52·4	11 03·2	
		1	A 1.	10 58·1	10 59·7	10 58·9	
		3	A 2.	10 48·6	11 14·0	11 01·3	
			A 1 L.	11 16·3	10 58·3	11 07·3	
		1	A 1 L.	10 46·0	11 14·2	11 00·1	
			A 2 L.	10 56·9	11 07·3	11 02·1	11 02·7
27.	Tondãno	1	A 1.	C.* 3·0	10 53·6	10 56·6	
			A 1 L.	C. 16·7	10 38·7	10 55·4	
			A 2 L.	C. 5·8	10 49·1	10 54·9	10 55·6
29.	Manãdo	1	A 1.	C. 3·0	10 42·4	10 45·4	
			A 1 L.	C. 16·7	10 29·1	10 45·8	
			A 2 L.	C. 5·8	10 37·6	10 43·4	10 44·9
	COCOS.						
Aug. 26.	Direction Island.	1	A 1.	C. 3·0	39 20·5	39 23·5	
			A 2.	39 16·4	C. 6·0	39 22·4	
			A 2 L.	39 18·1	C. 3·0	39 21·1	
		2	A 1.	40 14·8	38 27·6	39 21·2	
			A 2.	39 42·8	38 56·5	39 19·6	
			A 1 L.	39 30·2	39 16·4	39 18·5	
			A 2 L.	39 30·1	39 07·8	39 18·9	
Sept. 6.		3	A 2.	39 14·3	39 28·5	39 21·4	
			A 1 L.	39 28·8	39 12·8	39 20·8	
7.		3	A 2.	39 13·8	39 27·2	39 20·5	
			A 1 L.	39 27·8	39 08·8	39 18·3	
		2	A 1.	40 08·6	38 29·3	39 18·9	
			A 2.	39 40·6	38 56·1	39 18·3	
			A 1 L.	39 23·7	39 21·3	39 22·5	
			A 2 L.	39 29·7	39 09·7	39 19·7	
8.		1	A 1.	C. 3·0	39 17·1	39 20·1	
			A 1 L.	39 9·4	C. 6·0	39 15·4	
			A 2 L.	39 16·3	C. 3·0	39 19·3	
		2	A 1.	40 14·3	38 30·1	39 22·2	
			A 2.	39 35·3	39 05·3	39 20·3	
			A 1 L.	39 26·8	39 19·5	39 23·1	
			A 2 L.	39 30	39 05·6	39 17·8	
		3	A 2.	39 18	39 23·5	39 20·7	
			A 1 L.	39 26·6	39 12·0	39 19·3	
11.		1	A 1.	C. 3·0	39 18·0	39 21·0	
			A 1 L.	39 13·5	C. 6·0	39 19·5	
			A 2 L.	39 18·1	C. 3·0	39 21·1	
25.		1	A 1.	C. 3·0	39 18·0	39 21·0	
			A 1 L.	39 14·5	C. 6·0	39 20·5	
			A 2 L.	39 14·8	C. 3·0	39 17·8	
		2	A 1.	40 09·7	38 29·5	39 19·6	
			A 2.	39 34·6	38 55·1	39 14·8	
			A 1 L.	39 17·5	39 20	39 18·7	
			A 2 L.	39 31·4	39 05·3	39 18·4	
		3	A 2.	39 14·7	39 26·6	39 20·6	
			A 1 L.	39 30·0	39 15·3	39 22·6	39 20
Nov. 10.	Singapore ...	1	A 1.	C. 0	12 56·4	12 56·4	
			A 1 L.	12 35·0	C. 16·3	12 51·3	
			A 2 L.	12 55·0	C. 2·0	12 57·0	
13.		2	A 1.	13 59·5	11 48·2	12 53·8	
			A 2.	13 28·3	12 15·2	12 51·7	
			A 1 L.	12 46·6	12 57·7	12 52·1	
			A 2 L.	13 08·0	12 42·5	12 55·2	
		3	A 2.	12 39·4	13 14·0	12 56·7	
			A 1 L.	13 16·7	12 46·4	13 01·5	
14.		3	A 1 L.	13 15·3	12 49·2	13 02·2	
			A 2.	12 54·8	13 15·4	13 05·1	

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				—	—	—	South.
1848.							
Nov. 14.	Singapore ...	2	A 2 L.	13 16	12 55·6	13 04·8	
			A 1 L.	13 01·3	13 02·1	13 01·7	
			A 2.	13 28·8	12 20·5	12 54·6	
			A 1.	14 03·5	11 53·7	12 58·6	
		1	A 2 L.	12 57·6	C. 2	12 59·6	
			A 1 L.	12 44·1	C. 16·3	13 00·4	
			A 1.	C. 0	12 59·5	12 59·5	
		1	A 1.	C. 0	12 54·3	12 54·3	
			A 1 L.	12 41·2	C. 16·3	12 57·5	
			A 2 L.	12 54·3	C. 2·0	12 56·3	
		1	A 2 L.	12 56·7	C. 2·0	12 58·7	
			A 1 L.	12 45·6	C. 16·3	13 01·9	
			A 1.	C. 0	12 52·3	12 52·3	
24.		1	A 1.	C. 0	12 51·3	12 51·3	
			A 1 L.	12 41·1	16·3	12 57·4	
			A 2 L.	13 00·3	2·0	13 02·3	
		2	A 1.	14 03·4	11 48·4	12 55·9	
			A 2.	13 27·1	12 13·6	12 50·3	
			A 1 L.	13 02·3	13 07	13 04·6	
			A 2 L.	13 13·5	12 50·8	13 02·1	
		3	A 2.	13 06·2	12 51·8	12 59·0	
			A 1 L.	13 12·8	12 49·1	13 00·9	
		1	A 1.	C. 0	12 57·8	12 57·8	
			A 1 L.	12 45·6	C. 16·3	13 01·9	
			A 2 L.	12 57·0	C. 2	12 59·0	
		2	A 1.	14 01·9	11 51·5	12 56·6	
			A 2.	13 29·0	12 17·8	12 53·4	
			A 1 L.	12 58·2	13 05·8	13 02·0	
			A 2 L.	13 11·4	12 46·0	12 58·7	
		3	A 2.	12 53·6	13 16·2	13 04·9	
			A 1 L.	13 19·2	12 51·9	13 05·5	
		3	A 2.	12 45·2	13 11·5	12 58·2	
Dec. 1.			A 1 L.	12 45·6	13 18·3	13 01·9	
14.		3	A 2.	12 48·7	13 17·3	13 03·0	
			A 1 L.	12 52·8	13 21·5	13 07·1	
5.		3	A 2.	12 48·9	13 13·9	13 01·4	
15.			A 1 L.	13 20	12 47·8	13 03·9	
		3	A 2.	12 50·0	13 18·0	13 04·0	
			A 1 L.	13 19·2	12 47·4	13 03·3	
6.		3	A 2.	12 49·6	13 13·6	13 01·6	
15.			A 1 L.	13 15·5	12 43·2	12 59·3	
		3	A 2.	12 49·7	13 23·2	13 06·4	
			A 1 L.	13 25·3	12 46·7	13 06·0	
7.		3	A 2.	12 44·2	13 13	12 58·6	
16.			A 1 L.	13 13·8	12 49·9	13 01·8	
		3	A 2.	12 50·1	13 13·3	13 01·6	
			A 1 L.	13 16·7	12 48·8	13 02·7	
8.		3	A 2.	12 47·8	13 10·6	12 59·2	
16.			A 4 L.	13 11·7	12 46·8	12 59·2	
		3	A 1 L.	13 16·8	12 51·5	13 04·1	
			A 2.	12 47·3	13 14	13 00·7	
12.		1	A 1.	C. 0	12 55·3	12 55·3	
19.			A 1 L.	12 44·3	C. 16·3	13 00·6	
			A 2 L.	12 54·5	C. 2	12 56·5	
		1	A 2 L.	12 55·9	C. 2	12 57·9	
			A 1 L.	12 46·1	C. 16·3	13 02·4	
			A 1.	C. 0	12 58·6	12 58·6	
12.		2	A 1.	13 59	11 44·7	12 51·8	
28.			A 2.	13 26·9	12 14·5	12 50·7	
			A 1 L.	12 58·8	13 06·6	13 02·7	
			A 2 L.	13 09·7	12 47·7	12 58·7	
		2	A 2 L.	13 15·8	12 48·6	13 02·2	
			A 1 L.	13 03·7	13 08·3	13 06·0	
			A 2	13 30·1	12 14·1	12 52·1	
			A 1	14 06·5	11 47·2	12 56·8	
12.		3	A 2.	12 47·4	13 11·5	12 59·4	
Dec. 28.			A 1 L.	13 20	12 51·4	13 05·7	
		3	A 1 L.	13 21·2	12 48·5	13 04·8	
			A 2.	12 47·5	13 14·1	13 00·8	12 59 4

* C. the correction applied to the needle, the poles remaining unchanged.

Table F.

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				−	−	−	South.
1849.							−
Jan. 2.	Malacca	1	A 1.	C. ° ′ 0	11 27·4	11 27·4	
			A 1 L.	11 10·8	C. 16·3	11 27·1	
			A 2.	11 27·1	C. 2·0	11 29·1	
3.		2	A 1.	12 36·3	10 18·2	11 27·2	
			A 2.	12 04·9	10 48·7	11 26·8	
			A 1 L.	11 38·1	11 23·6	11 30·8	
			A 2 L.	11 42·0	11 13·2	11 27·6	
		3	A 2.	11 04·6	11 49·8	11 27·2	
			A 1 L.	11 43·2	11 12·0	11 27·6	11 27·9
10.	Pulo Dinding.	1	A 1.	7 31·3	7 31·6	7 31·4	
			A 1 L.	7 14·7	7 47·4	7 31·0	
			A 2 L.	7 26·9	7 30·9	7 28·9	
		2	A 1.	8 42·6	6 24·4	7 33·5	
			A 2.	8 07·4	6 58·7	7 33·0	
			A 1 L.	7 34·7	7 38·4	7 36·5	
			A 2 L.	7 50·3	7 27·7	7 39·0	
		3	A 2.	7 18·7	7 56·2	7 37·4	
			A 1 L.	7 46·1	7 22·4	7 34·2	7 33·9
20.	Pulo Penang .	1	A 1.	5 00·4	4 57·5	4 59·0	
			A 1 L.	4 34·3	5 11·0	4 52·6	
			A 2 L.	4 48·9	5 01·2	4 55·0	
		2	A 1.	6 07·8	3 40·2	4 54·0	
			A 2.	5 33·3	4 15·0	4 54·1	
			A 1 L.	4 58·3	4 55·0	4 56·6	
			A 2 L.	5 07·3	4 47·3	4 57·3	
25.		3	A 1 L.	5 07·9	4 48·8	4 58·3	
			A 2.	4 25·4	5 10·3	4 59·8	4 55·5
				+	+	+	North.
Feb. 5.	Car Nicobar...	1	A 1.	1 20	1 13·2	1 16·6	
			A 1 L.	1 35·1	1 01·5	1 18·3	
			A 2 L.	1 21·8	1 11·8	1 16·8	
6.		2	A 1.	0 07·1	2 28·6	1 17·8	
			A 2.	0 39·0	2 00·3	1 19·6	
			A 1 L.	1 18·2	1 22·3	1 20·2	
			A 2 L.	1 08·7	1 23·8	1 16·2	
12.		3	A 2.	1 38·2	0 52·9	1 15·5	+
			A 1 L.	1 05·6	1 32	1 18·8	1 17·8
							South.
17.	Noncowry Harbour.	3	A 1 L.	1 13·8	0 44·1	0 58·9	−
			A 2.	0 38·8	1 13	0 55·9	0 57·4
19.	Bompoko.....	3	A 1 L.	0 34·9	0 17·3	0 26·1	
			A 2	0 05·7	0 45·8	0 25·7	0 25·9
				+	+	+	+
Mar. 26.	Hastings' Island.	1	A 1.	4 30·5	4 35·0	4 32·7	North.
			A 1 L.	4 46·6	4 07·4	4 27·0	
			A 2 L.	4 38·7	4 22·6	4 30·6	

Date.	Name of Station.	Circle.	Needle.	Poles. Direct.	Poles. Reversed.	Dip.	Mean Dip.
				+	+	+	North.
1849.							+
	Hastings' Island.	2	A 1.	3 19·8	3 42·3	3 31·0	
			A 2.	3 51·3	5 11·4	4 31·3	
			A 1 L.	4 46	4 26·9	4 36·9	
			A 2 L.	4 30·5	4 44·7	4 32·6	
		3	A 2.	4 51	4 16·7	4 33·8	
			A 1 L.	4 11	4 58	4 34·5	4 32·2
April 14.	Moulmein ...	2	A 1.	16 41·4	18 49·4	17 45·4	
17.			A 2.	17 06·0	18 24·8	17 45·4	
21.			A 1 L.	17 58	17 52·3	17 55·1	
		1	A 1.	17 53·9	17 42·7	17 48·3	
			A 1 L.	17 54·5	17 43·1	17 48·8	
24.			A 2 L.	17 51	17 41·7	17 46·3	
		3	A 2.	18 07·8	17 31·7	17 49·7	
May 23.			A 1 L.	17 37·7	18 10	17 53·8	17 49·1
	Madras	3	A 1 L.	7 16·0	7 59·1	7 37·5	
		1	A 1.	7 38·4	7 34·5	7 36·5	
		1	A 1 L.	7 41·8	7 35·5	7 38·6	
		1	A 2 L.	7 47·6	7 32·0	7 39·8	
24.							
26.		2	A 1.	6 24·9	8 43·0	7 34·0	
			A 2.	6 55·9	8 11·7	7 33·8	
			A 1.	6 24·9	8 48·3	7 36·6	
			A 1 L.	7 44·1	7 37·1	7 40·6	
			A 2 L.	7 25·6	7 50·7	7 38·1	
		3	A 2.	7 59·0	7 17·5	7 38·2	
July 24.			A 1 L.	7 27·5	7 57·3	7 42·4	
		2	A 1.	6 28·6	8 52·2	7 40·4	
			A 2.	6 55·7	8 17·8	7 36·7	
			A 1 L.	7 46·3	7 29·9	7 38·1	
27.			A 2 L.	7 27·2	7 51·2	7 39·2	
		1	A 1.	7 35·3	7 37·7	7 36·5	
28.			A 1 L.	7 41·8	7 28·8	7 35·3	
		1	A 1 L.	7 47·0	7 29·5	7 38·2	
		3	A 2.	7 59·5	7 14·5	7 38·0	
Aug. 30.		3	A 1 L.	7 25·5	7 56·7	7 41·1	
		1	A 1.	7 35·6	7 33·1	7 34·3	
		1	A 1 L.	7 37·6	7 29·7	7 33·6	
		1	A 2 L.	7 48·8	7 27·9	7 38·3	
		2	A 1.	6 23·1	8 48·1	7 35·6	
		2	A 2.	6 54·5	8 17·8	7 36·1	
		2	A 1 L.	7 25·0	7 54·8	7 39·9	
		2	A 2 L.	7 22·2	7 54·7	7 38·4	
		3	A 2.	8 00·8	7 19·8	7 40·3	
		3	A 1 L.	7 23·3	7 53·3	7 38·3	7 37·7

TABLE F.

General Table containing the mean result of all the Dips determined both on Shore and at Sea, and the whole reduced to one common Epoch, viz. January 1, 1848.

Station.	Date.	Latitude.	Longitude.	Dip observed.	Dip deduced, Jan. 1, 1848.	Place of observation.
Singapore	April, 1846	+1° 18′ 32″ N.	103° 56′ 30″ E.	−12° 47·0 S.	−12° 51·8 S.	Magnetic Observatory.
Singapore	March, 1848	.....	.....	12 56·8	12 56·2	Magnetic Observatory.
Singapore	January, 1849	.....	.....	12 59·4	12 56·7	Magnetic Observatory.
BORNEO.						
Sarāwak	July, 1846	1 33 54	110 29 00	11 10·9	11 14·9	Near Sir J. Brooke's House.
Sambas		1 22 00	109 28 00	11 27·0	11 31·0	Resident's Garden.
Permanket		1 10 29	109 04 15	12 31·8	12 35·8	Near the mouth of the River.
Pontiānak	August, 1846	−0 01 19 S.	109 30 00	14 41·3	12 45·0	Garden of the Resident.
Succadāna		1 15 33	109 57 00	16 58·4	17 02·1	Garden of Assistant Resident.
JAVA.						
Batavia	Sept. 1846	6 09 52	106 58 00	27 03·00	27 06·6	Magnetic Observatory in the middle
Batavia	Nov. 1846	.....	.....	26 57·2	27 00·2	of a large rice-field, termed Sāwa
Batavia		.....	.....	27 02·4	27 05·4	Besār.
Batavia	July, 1847	.....	.....	27 08·2	27 09·5	
Ceram	October, 1846	6 07 05	106 15 00	27 11·0	27 14·2	Garden of Resident.
Anjeer		6 02 47	106 01 00	26 28·8	26 32	Garden of Assistant Resident.
Cheringin		6 22 05	105 56 45	27 30·8	27 34	Garden of Assistant Resident.
Palambangan		6 31 00	105 54 45	28 05·4	28 08·6	Garden of Bungalow.
Chebiliang		6 47 00	105 49 15	28 37·9	28 41·1	Garden of Bungalow.
Chelangkahan		6 54 00	106 06 45	28 20·7	28 23·9	
Goonong Dādap		6 28 00?	106 06 00	27 28·5	27 31·7	Close to the Public Bungalow.
Woorong Goonong		6 11 00?	106 10 00?	27 20·0	27 23·2	Near the Assistant Resident's House.
Tankāra		6 08 00?	106 40 00?	27 02·6	27 05·8	Garden of Assistant Resident.
Tegu	December.	6 43 04	106 58 45	28 42·4	28 45·4	Garden of Bungalow.
Pangerango		6 51 00	106 59 00	29 42·7	29 45·7	Top of the Mountain near the Bun-
Chunjūr		6 50 08	107 09 45	28 23·1	28 26·1	Garden of Resident. [galow.
Kārang Tengga		6 58 16	106 47 45	28 21·1	28 24·1	Garden of Bungalow.
Chebrānok		6 57 14	106 25 30	28 27·8	28 30·8	Close to the River.
Wine Cooper's Bay		7 05 00?	106 36 00	29 18·5	29 21·5	Garden of Bungalow.
Chilotoe		7 11 17	106 27 00	28 51·3	28 54·3	Garden of Bungalow.
Pangangbahan		7 30 37	106 19 00	29 41·4	29 44·4	Garden of Bungalow.
Mooāro Chikasso		7 28 00	106 38 00	30 05·3	30 08·3	Garden of Bungalow.
Sidang Bārang		7 30 00	107 10 00	30 12·0	30 15·0	Garden of Bungalow.
Bejong Petair		7 13 36	107 02 00	29 33·5	29 36·5	Garden of Bungalow.
Bandong		6 55 44	107 40 30	28 31·4	28 34·4	Garden of Regent.
Garoet		7 13 54	107 55 00	28 58·5	29 01·5	Garden of Bungalow.
Permangpek		7 39 23	107 45 15	30 11·8	30 14·8	Garden of Bungalow.
Cherūgnūktok	January, 1847	7 38 25	108 09 45	30 08·2	30 10·9	Garden of Bungalow.
Kālipoochen		7 39 02	108 52 30	29 51·2	29 53·9	Garden of Assistant Resident.
Banjeer		7 23 08	108 42 00	29 07·2	29 09·9	Garden of Bungalow.
Chāwee		7 09 34	108 23 00	28 39·2	28 41·9	Garden of Bungalow.
Samadang		6 51 14	108 04 45	27 57·5	28 00·2	Garden of Inn.
Cheribon		6 43 34	108 42 00	27 49·3	27 52·0	Garden of Inn.
Indramāyu	February.	6 19 35	108 25 45	27 28·5	27 30·9	Garden of Assistant Resident.
Tegal		6 51 57	109 15 30	28 02·7	28 05·1	Garden of Inn.
Samārang		6 59 42	110 30 45	27 02·2	27 04·6	Mr. M'Lachlan's Garden.
Japara		6 36 07	110 38 15	27 27·5	27 29·9	Garden of Regent.
Ambarāwa		7 16 08	110 28 45	29 25·3	29 27·7	Garden of General Van der Wyck.
Balembang		7 24 00?	110 37 30	29 00·0	29 02·4	Garden of Mr. Forrestier.
Solo		7 35 00	110 53 30	29 10·3	29 12·7	Garden near the Inn.
Nyāwee	March.	7 23 52	111 29 15	28 57·7	28 59·9	Garden of Engineer Commandant.
Bankāwa		7 00 26	112 21 00	27 45·1	27 47·3	On the bank of the River Solo.
Soorabāya		7 16 01	112 44 30	28 50·8	28 53·0	Mr. Frazer's garden. [lace-
Sūmenap	April.	7 00 26	113 51 15	27 43·8	27 45·8	Ground in front of the Sultan's Pa-
Pulo Kuneeang		6 51 32	115 16 30	27 23·6	27 25·6	Garden of Bungalow.
Bezooki	May.	7 43 29	113 42 45	29 05·7	27 07·5	Garden of Resident.
Kedeeri		7 48 29	112 00 00	29 50·4	29 52·2	Garden of Resident.
Patchitan	June.	8 12 56	111 05 30	30 34·5	30 36	Garden of Resident.
Munoori		7 35 22	110 04 00	29 19·0	29 20·5	Garden of Bungalow.
Kārang Bolong		7 45 44	109 27 00	29 54·4	29 55·9	Garden of Bungalow.
Chilāchap		7 44 29	108 57 15	29 44·3	29 45·8	Garden of Bungalow.
Aji Bārang		7 24 49	109 03 30	27 20·8	27 22·1	Garden of Bungalow.
SUMATRA.						
Telok Betoug, Lampong Bay	September.	5 26 12	105 20 15	26 14·8	26 15·7	Garden of Assistant Resident.
Poolo Bay, near Bencoolen		3 53 54	102 28 45	23 53·1	23 54·0	Close to the Bay.
Padang	November.	0 58 58	100 31 15	18 31·7	18 32·2	Near the sea-shore.
Solok		0 47 05 S.	100 55 45 E.	17 53 S.	17 50·8 S.	Garden of Commandant.

TABLE F.

Station.	Date.	Latitude.	Longitude.	Dip observed.	Dip deduced, Jan. 1, 1848.	Place of observation.
SUMATRA.						
Sijonjong	Nov. 1847 ...	−0° 41′ 47″ S.	101° 19′ 30″ E.	−17° 49·3 S.	−17° 49·8 S.	Garden of Commandant.
Bua Pānjang		0 28 09	101 08 00	17 10·9	17 11·4	Garden of Commandant.
Pāyacombo		0 13 10	101 04 45	16 37·7	16 38·2	Garden of Commandant.
Fort Vande Capellen		0 27 34	101 03 00	17 11·8	17 12·3	Garden of Commandant.
Padang Panjang		0 22 00?	100 42 30	17 47·0	17 47·5	Garden of Inn.
Fort de Kock	December.	0 13 00?	100 27 15	16 59·4	16 59·6	Garden of Assistant Resident.
Menindjo		0 13 00?	100 14 00	17 00·4	17 00·6	Garden of Assistant Resident.
Balembangan		0 11 44	100 10 15	16 47·1	16 47·3	Garden of Assistant Resident.
Peesang		0 07 55	100 12 00	16 33·2	16 33·4	Garden of Bungalow.
Bonjol		0 00 52	100 13 00	16 38·3	16 38·5	Garden of Assistant Resident.
Loobisikapping		+0 06 55 N.	.....	16 08·1	16 08·3	Garden of Controleur.
Batoo Bedindi		0 16 00	.....	15 49·0	15 49·2	Garden of Bungalow.
Lender		0 24 24	100 04 00	15 35·0	15 35·2	Garden of Bungalow.
Rau		0 33 07	99 56 45	15 37·2	15 37·4	Garden of Assistant Resident.
Pionghay		0 36 19	99 52 15	15 50·0	15 50·2	Garden of Bungalow.
Batong		0 39 00	99 47 15	15 41·3	15 41·5	Garden of Bungalow.
Kotanopan		0 42 00	99 42 45	15 19·7	15 19·9	Garden of Bungalow.
Tāna Bātoo		0 44 26	99 30 45	15 02·9	15 03·1	Garden of Bungalow.
Fort Elout		0 50 56	99 32 20	14 47·9	14 48·1	Garden of Bungalow.
Singalāngan		1 14 48	.....	14 11·7	14 11·9	Garden of Bungalow.
Padang Sidompang		1 22 33	99 22 45	13 46·8	13 47·0	Garden of Commandant.
Sibogha		1 44 42	98 56 15	13 02·3	13 02·5	Garden of Resident.
Bāres		2 00 51	98 31 30	12 57·8	12 58·0	Garden of Assistant Resident.
Sinkel		2 16 37	97 51 35	12 23·3	12 23·5	Garden of Commandant.
Pulonias, Goonong Satoolie	Jan. 1848.....	1 17 35	97 40 30	14 05·6	14 05·8	Garden of Commandant.
Nātal		0 33 44	99 20 15	15 32·2	15 32·4	Garden of Assistant Resident.
Mount Ophir, near Malācca	April 1848 ...	2 22 ?	102 38 ?	9 55·8	9 55·1	Top of Mount Ophir.
At sea	Apr. 25.	2 20	107 11	9 56·8	9 56·1	At sea.
At sea	Apr. 26.	2 17	107 49	9 25·6	9 24·9	At sea.
At sea	Apr. 27.	2 42	108 03	9 57·4	9 56·7	At sea.
At sea	Apr. 28.	2 48	109 25	8 39·8	8 39·1	At sea.
At sea	Apr. 29.	3 19	111 18	7 17·0	7 16·3	At sea.
At sea	May 1.	4 45	113 45	4 06·6	4 05·6	At sea.
	May 2.	5 16	115 16	2 53·7	2 52·7	At sea.
Pulo Labooan	May.	5 16 59	115 18 15	2 52·6	2 51·6	Near the flag-staff.
At sea	May 11.	5 41	115 05	1 33·1	1 32·1	At sea.
At sea	May 12.	6 23	116 09	+ 0 03·7 N.	+ 0 02·7 N.	At sea.
At sea	May 13.	7 25	117 18	1 46·6	1 45·6	At sea.
At sea	May 14.	7 11	118 44	1 32·6	1 31·6	At sea.
At sea	May 15.	7 07	119 50	1 34·3	1 33·3	At sea.
At sea	May 16.	7 15	120 30	1 33·8	1 32·8	At sea.
At sea	May 17.	7 13	120 44	1 26·8	1 25·8	At sea.
At sea	May 18.	6 54	121 30	0 37·4	0 36·4	At sea.
At sea	May 19.	7 03	121 18	0 50·6	0 49·6	At sea.
At sea	May 20.	7 09	121 50	0 57·7	0 56·7	At sea.
Sambooanga	June.	6 54 20	122 13 45	1 19·3	1 18·2	On the spot where Sir E. BELCHER
At sea	June 3.	6 25	122 44	− 0 25·0 S.	− 0 23·9 S.	observed.
At sea	June 5.	5 19	125 03	2 34·5	2 33·4	At sea.
At sea	June 6.	4 24	124 00	4 14·5	4 13·4	At sea.
At sea	June 7.	3 56	124 40	5 17·2	5 16·1	At sea.
At sea	June 8.	3 34	124 20	5 42·6	5 41·6	At sea.
At sea	June 9.	3 37	125 30	5 50·4	5 49·3	At sea.
At sea	June 10.	3 20	125 00	6 22·2	6 21·1	At sea.
At sea	June 11.	3 02	125 21	6 56·6	6 55·5	At sea.
At sea	June 12.	2 26	125 24	8 18·0	8 16·9	At sea.
At sea	June 13.	1 59	125 27	8 54·0	8 52·9	At sea.
At sea	June 14.	1 47	125 27	9 44	9 42·9	At sea.
At sea	June 15.	1 34	125 21	9 57·1	9 56·0	At sea.
Keemah	July.	1 21 55	125 07 59	11 02·7	11 01·4	In a garden near the village.
Tondāno	July.	1 17 31	124 59 11	10 55·6	10 54·3	Garden of Missionary.
Manādo	July.	1 29 11	124 51 11	10 44·9	10 43·6	Garden near the fort.
At sea	July 7.	0 38 51	126 29	11 48·6	11 47·5	At sea.
At sea	July 8.	0 26 52	127 05	12 44·5	12 43·2	At sea.
At sea	July 10.	−0 11 S.	128 42	13 51·2	13 49·9	At sea.
At sea	July 11.	0 33	127 55	14 24·5	14 23·2	At sea.
At sea	July 12.	1 25	128 00	16 42·1	16 40·8	At sea.
At sea	July 13.	1 32	128 05	16 33·1	16 31·8	At sea.
At sea	July 14.	1 29	128 12	16 48·7	16 47·4	At sea.
At sea	July 15.	2 13	127 57	17 28·3	17 27·0	At sea.
At sea	July 17.	2 55	126 00	19 14·5	19 13·2	At sea.
At sea	July 21.	4 20	123 10	22 21·7	22 20·4	At sea.
At sea	July 22.	5 05	122 30	23 39·6	23 38·3	At sea.
At sea	July 24.	5 46	121 03	25 03·5	25 02·2	At sea.
At sea	July 25.	5 51	−119 36	25 18·3	25 17·0	At sea.

TABLE F.

Station.	Date.	Latitude.	Longitude.	Dip observed.	Dip deduced, Jan. 1, 1848.	Place of observation.
SUMATRA.		° ′ ″	° ′ ″	° ′	° ′	
At sea	July 28, 1848	− 5 34 S.	113 20 E.	−25 26·1 S.	25 24·8 S.	At sea.
At sea	July 29.	5 30	110 12	25 21·1	25 19·8	At sea.
At sea	July 31.	5 58	106 55	26 24·1	26 22·8	At sea.
At sea	Aug. 12.	6 10	107 04	26 47·8	26 46·3	At sea.
At sea	Aug. 16.	6 04	105 27	26 32·0	26 30·5	At sea.
At sea	Aug. 17.	6 32	105 00	27 29·7	27 28·2	At sea.
At sea	Aug. 20.	6 35	104 45	27 36·7	27 35·2	At sea.
Cocos or Keeling Island	September.	12 05 38	96 50 30	39 20·0	39 18·5	Cocoa Nut Plantation, Direction [Island.
At sea	Oct. 4.	6 12	103 30	27 03·6	27 01·6	At sea.
At sea	Oct. 5.	5 38	103 17	25 40·3	25 38·3	At sea.
At sea	Oct. 22.	5 23	106 37	24 58·5	24 56·5	At sea.
At sea	Oct. 23.	3 24	105 58	21 46·7	21 44·7	At sea.
At sea	Oct. 24.	3 12	105 45	20 58·0	20 56·0	At sea.
At sea	Oct. 25.	2 51	105 38	20 23·2	20 21·2	At sea.
At sea	Oct. 26.	2 17	105 29	19 38·6	19 36·6	At sea.
At sea	Oct. 27.	2 06	104 44	19 19·9	19 17·9	At sea.
At sea	Oct. 30.	1 39	104 32	18 17·0	18 15·0	At sea.
At sea	Oct. 31.	1 23	105 07	17 59·8	17 57·8	At sea.
At sea	Nov. 1.	1 11	105 00	17 36·0	17 34·0	At sea.
At sea	Nov. 3.	+ 0 46 N.	105 20	14 03·2	14 01·0	At sea.
At sea	Nov. 4.	1 08	105 20	12 58·9	12 56·7	At sea.
At sea	Nov. 5.	1 16	103 55	13 15·2	13 13·0	At sea.
At sea	Jan. 1, 1849	1 40	102 51	12 04·1	12 01·4	At sea.
Malacca	Jan. 2.	2 11 19	102 17 00	11 27·9	11 25·2	Near the fort.
At sea	Jan. 4.	2 10	102 15	11 27·3	11 24·6	At sea.
At sea	Jan. 8.	3 54	100 25	7 44	7 41·3	At sea.
Pulo Dinding	January.	4 12 47	100 32 52	7 33·9	7 31·2	On the sea-shore.
Pulo Penang	February.	5 25 36	100 24 38	4 55·5	4 52·8	To the north and westward of Fort
At sea	Feb. 1.	7 53	97 13	0 03·3	0 00·3	At sea. [Cornwallis.
Car Nicobar	February.	9 10 12	92 48 23	+ 1 17·8 N.	+ 1 14·8 N.	On the sea-shore.
Noncowry Harbour		8 01 42	93 39 20	− 0 57·4 S.	− 0 54·4 S.	On an elevation near the shore.
Bompoko		8 14 05	93 19 20	0 25·9	0 22·9	In the village.
At sea	Mar. 19.	6 59	98 30	1 31·2	1 28·0	At sea.
At sea	Mar. 20.	8 06	97 34	+ 0 31·2 N.	+ 0 28·0 N.	At sea.
At sea	Mar. 21.	8 40	97 52	1 34·1	1 30·9	At sea.
At sea	Mar. 22.	9 11	98 10	2 49·0	2 45·8	At sea.
At sea	Mar. 23.	9 46	98 16	3 54·8	3 51·6	At sea.
Hastings' Island	Mar. 26.	10 06 45	98 21 15	4 22·2	4 19·0	On the sea-shore.
At sea	Mar. 29.	10 22	97 44	4 36·8	4 33·6	At sea.
At sea	Mar. 30.	11 01	97 30	5 52·2	5 49·0	At sea.
At sea	Mar. 31.	11 21	97 17	6 52·0	6 48·8	At sea.
At sea	April 2.	12 17	97 35	8 43·2	8 39·7	At sea.
At sea	April 3.	12 25	97 34	9 00·7	8 57·2	At sea.
At sea	April 5.	14 44	97 21	13 47·7	13 44·2	At sea.
At sea	April 6.	15 07	97 26	14 51·6	14 48·1	At sea.
At sea	April 7.	16 04	97 34	17 12·7	17 09·2	At sea.
Moulmein	April,	16 29 46	97 45 30	17 49·1	17 45·6	Garden of Captain Scott.
Madras	May,	13 04 09	80 16 00	7 37·7	7 34·2	Garden of Observatory.

TABLE G.

Absolute Horizontal Intensity at various Stations in the Eastern Archipelago, from observations made with the Induction Inclinometer, with the Observatory Unifilar Magnetometer, and with JONES's Portable Unifilar Magnetometer.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Inclinometer.	Results. m.	Results. X.	General mean.
1846.						seconds.				
Mar. 20.	Singapore.	H 12	D 5	1·20	2 34 00	1158·0	O	0·316	8·135	
				1·30	2 01 03			0·316	8·140	
				1·40	1 36 56			0·316	8·141	
				1·60	1 04 56			0·316	8·144	
				1·70	0 54 13			0·316	8·138	
				1·80	0 45 37			0·316	8·144	
				1·90	0 38 57			0·317	1·128	
				2·00	0 33 18			0·316	8·139	
				2·20	0 24 58			0 316	8·148	
		H 12	D 6	1·20	2 29 20	1170·4		0·306	8·112	
				1·30	1 57 32			0·306	8·121	
				1·40	1 34 01			0·305	8·127	
				1·50	1 16 26			0·306	8·119	
				1·60	1 03 02			0·306	8·116	
		H 12	D 6	1·70	0 52 38	1170·4		0·306	8·110	
				1·80	0 44 26			0·306	8·102	
				1·90	0 37 27			0·306	8·120	
				2·00	0 32 10			0·305	8·131	
				2·10	0 27 54			0 306	8·115	
				2·20	0 24 15			0·306	8·118	
				2·30	0 21 10			0·305	8·129	
28.		H 12	D 5	1·25	2 16 41	1158·0		0·317	8·133	
				1·30	2 01 31			0·316	8·133	
				1·35	1 48 30			0·316	8·136	
				1·40	1 37 13			0·316	8·139	
31.		H 11	D 5	1·25	2 17 40	1158·0	I.	0·318	8·098	
				1·30	2 02 20			0·318	8·101	
				1·35	1 49 10			0·318	8·105	
				1·40	1 37 55			0·318	8·114	
		H 11	D 6	1·25	2 12 22	1170·4		0·306	8·111	
				1·30	1 57 32			0·306	8·116	
				1·35	1 45 05			0·306	8·112	
				1·40	1 34 11			0·306	8·115	
April 1.		H 12	D 6	1·25	2 11 32		O.	0·305	8·134	
				1·30	1 57 02			0·305	8·132	
				1·35	1 44 33			0·305	8·131	
				1·40	1 33 40			0·305	8·135	
2.		H 11	A 8	1·15	2 10 19	1020·9		0·236	8 133	
				1·40	1 12 26			0·236	8·133	
3.		H 11	A 10	1·25	2 15 52	889·4		0·315	8·100	
				1·40	1 36 49			0·315	8·101	
		H 12	A 10	1·25	2 15 01		I.	0·314	8·114	
				1·40	1 36 17			0·314	8·111	
11.		H 12	A 6	1·20	2 13 43	949·2		0·276	8·129	
				1·40	1 24 28			0·276	8·133	
				1·20	2 14 46		I.	0·276	8·110	
				1·40	1 25 16			0·277	8·097	
		H 12	A 9	1·30	2 02 57	869·46	O.	0·321	8·108	
				1·40	1 38 30			0·320	8·117	
13.		H 11	A 9	1·30	2 03 45	868·10	I.	0·321	8·105	
				1·40	1 39 09			0·321	8·103	
		H 11	A 7	1·30	2 15 54	840·5		0·354	8·103	
				1·40	1 48 39			0·353	8·112	
		H 12	A 7	1·30	2 15 08		O.	0·353	8·118	
				1·40	1 48 16			0·353	8·116	8·121
1848.										
Feb. 18.		H 11	D 5	1·25	2 07 47	1202·5	I.	0·294	8·107	
				1·30	1 53 35			0·294	8·108	
				1·35	1 41 20			0·294	8·109	
				1·40	1 30 49			0·294	8·114	
		H 11	A 7	1·30	2 09 25	861·0		0·336	8·095	
				1·35	1 55 40			0·336	8·094	
				1·40	1 43 50			0·337	8·090	
				1·45	1 33 36			0·337	8·089	
		H 11	A 8	1·15	1 59 37	1064·7		0·216	8 127	
				1·20	1 45 20			0·216	8·124	
Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Inclinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Feb. 18.	Singapore.	H 11	A 8	1·25	1 35 12	1064·7	I.	0·216	8·131	
				1·30	1 22 59			0·217	8·124	
		H 11	A 9	1·25	2 14 59	881·4		0·312	8·105	
				1·30	2 00 03			0·312	8·108	
				1·35	1 47 13			0 312	8·109	
				1·40	1 36 14			0·312	8·105	
		H 11	A 10	1·25	1 58 39	951·3		0·274	8·113	
				1·30	1 45 27			0·274	8·116	
				1·35	1 34 10			0·274	8·117	
				1·40	1 24 29			0·274	8·115	
Mar. 7.		H 12	D 5	1·25	2 07 05	1202·5	O.	0·294	8·124	
				1·30	1 52 53			0·293	8·130	
				1·35	1 40 44			0·293	8·132	
				1·40	1 30 22			0·293	8·131	
		H 12	A 7	1·30	2 08 44	861·0		0·336	8·113	
				1·35	1 54 58			0·336	8·114	
				1·40	1 43 12			0·336	8·111	
				1·45	1 32 48			0·335	8·116	
		H 12	A 8	1·15	1 59 09	1064·7		0·216	8·135	
				1·20	1 45 06			0·216	8·130	
				1·25	1 32 53			0·216	8·142	
				1·30	1 22 35			0·216	8·140	
		H 12	A 9	1·25	2 14 22	881·4		0·312	8·101	
				1·30	1 59 38			0·312	8·099	
				1·35	1 46 53			0·312	8·099	
				1·40	1 35 48			0·312	8·103	
		H 12	A 10	1·25	1 58 19	951·3		0·275	8·094	
				1·30	1 45 07			0·275	8·102	
				1·35	1 33 54			0·275	8·102	
				1·40	1 24 16			0·275	8·100	
Feb. 19.		H 11	D 5	1·25	2 06 58	1202·5	I.	0·293	8·132	
				1·30	1 55 02			0·293	8·126	
				1·35	1 46 50			0·293	8·131	
				1·40	1 30 20			0·293	8·134	
		H 11	A 7	1·30	2 09 08	861·0		0·336	8·101	
				1·35	1 55 13			0·336	8·107	
				1·40	1 43 20			0·336	8·107	
				1·45	1 32 58			0·336	8·110	
		H 11	A 8	1·15	1 59 23	1064·7		0·216	8·127	
				1·20	1 45 12			0·216	8·126	
				1·25	1 33 10			0·216	8·130	
				1·30	1 22 52			0·216	8·126	
		H 11	A 9	1·25	2 14 29	881·4		0·311	8·121	
				1·30	1 59 25			0·311	8·128	
				1·35	1 46 44			0·311	8·124	
				1·40	1 35 47			0·311	8·121	
		H 11	A 10	1·25	1 58 26	951·3		0·274	8·119	
				1·30	1 45 23			0·274	8·117	
				1·35	1 34 07			0·274	8·117	
				1·40	1 24 26			0·274	8·115	
Mar. 8.		H 12	D 5	1·25	2 06 50	1202·5	O.	0·293	8·134	
				1·30	1 52 44			0·293	8·137	
				1·35	1 40 41			0·293	8·137	
		H 12	A 7	1·30	2 08 50	861·0		0·336	8·112	
				1·35	1 55 09			0·336	8·111	
				1·40	1 43 20			0·336	8·108	
				1·45	1 32 59			0·334	8·111	
		H 12	A 8	1·15	1 58 48	1064·7		0·216	8·149	
				1·20	1 44 57			0·216	8·138	
				1·25	1 32 54			0·216	8·143	
				1·30	1 22 32			0·216	8·145	
		H 12	A 9	1·25	2 14 17	881·4		0·312	8·099	
				1·30	1 59 21			0·312	8·099	
				1·35	1 46 38			0·312	8·108	
				1·40	1 35 35			0·312	8·111	
		H 12	A 10	1·25	1 58 17	951·3		0·275	8·094	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Mar. 9.	Singapore.	H 12	A 10	1·30	1 45 10	951·3	O.	0·275	8·098	
				1·35	1 33 56			0·275	8·100	
				1·40	1 24 26			0·275	8·091	
Feb. 21.		H 11	D 5	1·25	2 07 20	1202·5	I.	0·294	8·118	
				1·30	1 53 08			0·294	8·121	
				1·35	1 41 01			0·294	8·121	
				1·40	1 30 52			0·294	8·108	
		H 11	A 7	1·30	2 09 12	861·0		0·336	8·098	
				1·35	1 55 23			0·336	8·100	
				1·40	1 43 32			0·336	8·100	
				1·45	1 33 16			0·336	8·095	
		H 11	A 8	1·15	1 59 41	1064·7		0·217	8·116	
				1·20	1 45 32			0·217	8·113	
				1·35	1 33 22			0·217	8·120	
				1·40	1 23 01			0·217	8·118	
		H 11	A 9	1·25	2 14 50	881·4		0·312	8·110	
				1·30	1 59 53			0·312	8·113	
				1·35	1 47 05			0·312	8·111	
				1·40	1 36 02			0·312	8·111	
		H 11	A 10	1·25	1 58 39	951·3	I.	0·274	8·111	
				1·30	1 45 29			0·274	8·113	
				1·35	1 34 12			0·274	8·113	
				1·40	1 24 31			0·274	8·111	
Mar. 10.		H 12	D 5	1·25	2 06 32	1202·5	O.	0·293	8·141	
				1·30	1 52 47			0·293	8·133	
				1·35	1 40 23			0·293	8·147	
				1·40	1 30 05			0·293	8·141	
		H 12	A 7	1·30	2 08 39	861·0		0·335	8·115	
				1·35	1 54 54			0·335	8·117	
				1·40	1 43 23			0·336	8·104	
				1·45	1 32 52			0·336	8·113	
		H 12	A 8	1·15	1 59 41	1064·7		0·216	8·139	
				1·20	1 44 49			0·216	8·140	
				1·25	1 32 48			0·216	8·145	
				1·30	1 22 25			0·216	8·148	
13.		H 12	A 9	1·25	2 14 12	881·4		0·312	8·107	
				1·30	1 59 17			0·312	8·111	
				1·35	1 46 39			0·312	8·108	
				1·40	1 35 41			0·312	8·108	
		H 12	A 10	1·25	1 57 54	951·3		0·274	8·108	
				1·30	1 44 50			0·274	8·112	
				1·35	1 33 40			0·274	8·112	
				1·40	1 24 01			0·274	8·106	
Feb. 22.		H 11	D 5	1·25	2 07 21	1202·5	I.	0·294	8·118	
				1·30	1 53 09			0·294	8·120	
				1·35	1 41 01			0·294	8·121	
				1·40	1 30 46			0·294	8·112	
		H 11	A 7	1·30	2 09 16	861·0		0·336	8·095	
				1·35	1 55 31			0·336	8·094	
				1·40	1 43 38			0·336	8·093	
				1·45	1 33 14			0·336	8·096	
		H 11	A 8	1·15	1 59 46	1064·7		0·217	8·113	
				1·20	1 45 25			0·217	8·117	
				1·25	1 33 23			0·217	8·119	
				1·30	1 23 00			0·217	8·114	
		H 11	A 9	1·25	2 15 00	881·4		0·312	8·106	
				1·30	2 00 08			0·312	8·103	
				1·35	1 47 20			0·312	8·108	
				1·40	1 36 16			0·312	8·101	
		H 11	A 10	1·25	1 58 47	951·3		0·274	8·107	
				1·30	1 45 37			0·274	8·108	
				1·35	1 34 19			0·274	8·109	
				1·40	1 24 41			0·274	8·104	
Mar. 14.		H 12	D 5	1·25	2 06 39	1202·5	O.	0·293	8·137	
				1·30	1 52 43			0·293	8·136	
				1·35	1 40 46			0·293	8·134	
				1·40	1 30 10			0·293	8·139	
		H 12	A 7	1·30	2 08 31	861·0		0·335	8·118	
				1·35	1 54 56			0·336	8·113	
				1·40	1 43 07			0·336	8·112	
1848.						seconds.				
Mar. 14.	Singapore.	H 12	A 7	1·45	1 32 41	861·0	O.	0·335	8·119	
		H 12	A 8	1·15	1 59 00	1064·7		0·216	8·139	
				1·20	1 44 38			0·216	8·147	
				1·25	1 32 44			0·216	8·148	
				1·30	1 22 28			0·216	8·145	
		H 12	A 9	1·25	2 14 03	881·4		0·312	8·110	
				1·30	1 59 11			0·312	8·112	
				1·35	1 46 27			0·311	8·114	
				1·40	1 35 28			0·311	8·115	
17.		H 12	A 10	1·25	1 58 13	951·3		0·275	8·096	
				1·30	1 45 04			0·275	8·102	
				1·35	1 33 34			0·274	8·116	
				1·40	1 24 08			0·274	8·106	
Feb. 23.		H 11	D 5	1·25	2 07 05	1202·5	I.	0·293	8·129	
				1·30	1 52 55			0·293	8·131	
				1·35	1 40 52			0·293	8·130	
				1·40	1 30 15			0·293	8·129	
		H 11	A 7	1·30	2 08 56	861·0		0·336	8·111	
				1·35	1 55 14			0·336	8·109	
				1·40	1 43 29			0·336	8·104	
				1·45	1 33 00			0·336	8·110	
24.		H 11	A 8	1·15	1 59 29	1064·7		0·216	8·126	
				1·20	1 45 22			0·217	8·122	
				1·25	1 33 18			0·216	8·126	
				1·30	1 22 48			0·216	8·132	
		H 11	A 9	1·25	2 15 01	881·4	I.	0·312	8·106	
				1·30	2 00 02			0·312	8·108	
				1·35	1 47 03			0·311	8·114	
				1·40	1 36 03			0·312	8·112	
		H 11	A 10	1·25	1 58 37	951·3		0·274	8·114	
				1·30	1 45 31			0·274	8·113	
				1·35	1 34 04			0·274	8·120	
				1·40	1 24 29			0·274	8·114	
Mar. 10.		H 12	D 5	1·25	2 06 38	1202·5	O.	0·293	8·137	
				1·30	1 52 33			0·293	8·140	
				1·35	1 40 34			0·293	8·138	
				1·40	1 30 08			0·293	8·140	
		H 12	A 7	1·30	2 09 01	861·0		0·336	8·101	
				1·35	1 55 22			0·336	8·097	
				1·40	1 43 20			0·336	8·102	
				1·45	1 32 56			0·336	8·107	
		H 12	A 8	1·15	1 58 55	1064·7		0·216	8·141	
				1·20	1 44 48			0·216	8·140	
				1·25	1 32 49			0·216	8·143	
				1·30	1 22 31			0·216	8·142	
		H 12	A 9	1·25	2 14 10	881·4		0·312	8·109	
				1·30	1 59 26			0·312	8·107	
				1·35	1 46 40			0·312	8·108	
				1·40	1 35 45			0·312	8·106	
		H 12	A 10	1·25	1 58 19	951·3		0·275	8·096	
				1·30	1 45 11			0·275	8·100	
				1·35	1 34 00			0·275	8·099	
				1·40	1 24 11			0·274	8·106	8·116
Nov. 16.		H 11	D 5	1·25	2 04 47	1215·9	I.	0·288	8·114	
				1·30	1 50 59			0·288	8·113	
				1·35	1 39 04			0·288	8·114	
				1·40	1 28 47			0·287	8·116	
17.		H 11	A 7	1·30	2 06 41	867·7		0·331	8·127	
				1·35	1 53 13			0·331	8·125	
				1·40	1 41 38			0·331	8·122	
				1·45	1 31 36			0·331	8·117	
		H 11	A 8	1·15	1 55 17	1085·3		0·208	8·098	
				1·20	1 41 31			0·208	8·099	
				1·25	1 29 57			0·208	8·097	
				1·30	1 19 54			0·208	8·103	
25.		H 11	A 9	1·25	2 13 14	886·7		0·308	8·109	
				1·30	1 58 17			0·308	8·116	
				1·35	1 45 46			0·308	8·111	
				1·40	1 34 52			0·308	8·110	
		H 11	A 10	1·25	1 57 20	956·8		0·271	8·104	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r_1, r_2, r_3 &c.	Exp. of deflec. Angles. a, a', a'' &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Nov. 25.	Singapore.	H 11	A 10	1·30	1 44 19	956·8	I.	0·271	8·105	
				1·35	1 33 09			0·271	8·106	
				1·40	1 23 33			0·271	8·105	
16.		B.	D 5	1·05	3 29 31	1215·9	J.	0·287	8·121	
				1·10	3 02 16			0·287	8·122	
				1·15	2 39 26			0·287	8·125	
				1·20	2 20 33			0·287	8·120	
				1·25	2 04 06			0·287	8·129	
				1·30	1 50 26			0·287	8·126	
				1·35	1 38 41			0·287	8·123	
				1·40	1 28 29			0·287	8·123	
		B.	A 7	1·10	3 27 46	867·7		0·331	8·114	
				1·15	3 02 04			0·331	8·114	
				1·20	2 40 20			0·331	8·117	
				1·25	2 22 01			0·331	8·117	
				1·30	2 09 14			0·331	8·119	
				1·35	1 52 53			0·331	8·119	
				1·40	1 41 16			0·331	8·119	
				1·45	1 31 10			0·331	8·120	
		B.	A 8	0·95	3 22 50	1085·3		0·208	8·119	
				1·00	2 54 06			0·208	8·119	
				1·05	2 30 25			0·208	8·123	
				1·10	2 11 01			0·208	8·121	
				1·15	1 54 50			0·208	8·117	
				1·20	1 41 08			0·208	8·118	
				1·25	1 29 32			0·208	8·117	
				1·30	1 19 36			0·208	8·119	
		B.	A 9	1·05	3 43 46	886·7		0·309	8·088	
				1·10	3 14 55			0·309	8·088	
				1·15	2 50 46			0·309	8·088	
				1·20	2 30 15			0·308	8·092	
				1·25	2 13 07			0·309	8·077	
				1·30	1 58 19			0·309	8·083	
				1·35	1 45 45			0·309	8·083	
				1·40	1 34 52			0·309	8·084	
17.		B.	A 10	1·05	3 16 06	956·8		0·271	8·097	
				1·10	2 50 42			0·271	8·099	
				1·15	2 29 30			0·271	8·101	
				1·20	2 11 45			0·271	8·100	
				1·25	1 56 37			0·271	8·101	
				1·30	1 43 43	956·8		0·271	8·103	
				1·35	1 32 44			0·271	8·101	
				1·40	1 23 08			0·271	8·104	
		H 12	D 5	1·05	3 29 38	1215·9	O.	0·287	8·118	
				1·10	3 02 02			0·287	8·126	
				1·15	2 39 16			0·287	8·128	
				1·20	2 20 09			0·287	8·128	
				1·25	2 04 01			0·287	8·130	
				1·30	1 50 15			0·287	8·131	
				1·35	1 38 27			0·287	8·132	
				1·40	1 28 16			0·287	8·132	
		H 12	A 7	1·10	3 28 25	867·7		0·332	8·099	
				1·15	3 02 25			0·332	8·104	
				1·20	2 40 30			0·331	8·111	
				1·25	2 22 09			0·331	8·114	
				1·30	2 06 19			0·331	8·117	
				1·35	1 53 49			0·331	8·119	
				1·40	1 41 16			0·331	8·117	
				1·45	1 31 07			0·331	8·121	
18.		H 12	A 8	0·95	3 22 28	1085·3		0·207	8·125	
				1·00	2 53 42			0·207	8·128	
				1·05	2 30 05			0·207	8·131	
				1·10	2 10 45			0·207	8·128	
				1·15	1 54 28			0·207	8·129	
				1·20	1 40 38			0·207	8·137	
				1·25	1 29 08			0·207	8·135	
				1·30	1 19 04			0·207	8·137	
		H 12	A 9	1·05	3 43 58	886·7		0·309	8·084	
				1·10	3 14 48			0·309	8·089	
				1·15	2 50 40			0·309	8·089	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r_1, r_2, r_3 &c.	Exp. of deflec. Angles. a, a', a'' &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Nov. 18.	Singapore.	H 12	A 9	1·20	2 30 07	886·7	O.	0·308	8·095	
				1·25	2 12 52			0·309	8·084	
				1·30	1 58 11			0·309	8·086	
				1·35	1 45 34			0·309	8·088	
				1·40	1 34 45			0·309	8·088	
		H 12	A 10	1·05	3 16 23	956·8		0·271	8·090	
				1·10	2 50 48			0·271	8·096	
				1·15	2 29 32			0·271	8·099	
				1·20	2 11 46			0·271	8·099	
				1·25	1 56 41			0·271	8·098	
				1·30	1 43 45			0·271	8·101	
				1·35	1 32 39			0·271	8·103	
				1·40	1 23 12			0·271	8·101	
Dec. 1.		H 11	D 5	1·25	2 04 44	1215·9	I.	0·287	8·117	
				1·30	1 50 53			0·287	8·117	
				1·35	1 38 59			0·288	8·118	
				1·40	1 28 38			0·287	8·124	
		H 11	A 7	1·30	2 07 00	867·7		0·331	8·121	
				1·35	1 53 26			0·331	8·122	
				1·40	1 41 48			0·332	8·120	
				1·45	1 31 41			0·331	8·118	
		H 11	A 8	1·15	1 55 02	1085·3		0·208	8·110	
				1·20	1 41 20			0·208	8·110	
				1·25	1 29 47			0·208	8·108	
				1·30	1 19 53			0·208	8·107	
2.		H 11	A 9	1·25	2 13 36	886·7		0·308	8·100	
				1·30	1 58 48			0·308	8·100	
				1·35	1 46 07			0·308	8·100	
				1·40	1 35 14			0·308	8·097	
		H 11	A 10	1·25	1 57 25	956·8		0·271	8·104	
				1·30	1 44 24			0·271	8·104	
				1·35	1 33 15			0·271	8·104	
				1·40	1 23 41			0·271	8·101	
1.		B.	D 5	1·05	3 29 07	1215·9	J.	0·287	8·131	
				1·10	3 01 59			0·287	8·130	
				1·15	2 39 08			0·287	8·135	
				1·20	2 20 12			0·287	8·132	
				1·25	2 04 02			0·287	8·133	
				1·30	1 50 14			0·287	8·135	
				1·35	1 38 28			0·287	8·135	
				1·40	1 28 30			0·287	8·125	
4.		B.	A 7	1·10	3 27 58	867·7		0·331	8·111	
				1·15	3 02 14			0·331	8·112	
				1·20	2 40 46			0·332	8·107	
				1·25	2 22 02			0·331	8·117	
				1·30	2 06 24			0·331	8·117	
				1·35	1 52 51			0·331	8·121	
				1·40	1 41 17			0·331	8·120	
				1·45	1 31 08			0·331	8·124	
10.		B.	A 8	0·95	3 22 22	1085·3		0·207	8·129	
				1·00	2 53 48			0·207	8·127	
				1·05	2 30 13			0·207	8·129	
				1·10	2 10 39			0·207	8·133	
				1·15	1 54 37			0·207	8·126	
				1·20	1 40 59			0·208	8·124	
				1·25	1 29 25			0·208	8·123	
				1·30	1 19 39			0·207	8·136	
4.		B.	A 9	1·05	3 43 01	886·7		0·308	8·101	
				1·10	3 14 09			0·308	8·102	
				1·15	2 50 05			0·308	8·102	
				1·20	2 29 43			0·308	8·106	
				1·25	2 12 33			0·308	8·093	
				1·30	1 57 54			0·308	8·095	
				1·35	1 45 24			0·308	8·095	
				1·40	1 34 35			0·308	8·094	
6.		B.	A 10	1·05	3 16 21	956·8		0·271	8·091	
				1·10	2 50 57			0·271	8·093	
				1·15	2 29 46			0·271	8·093	
				1·20	2 11 50			0·271	8·097	
				1·25	1 56 40			0·271	8·099	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Dec. 6.	Singapore.	B.	A 10	1·30	° ′ ″ 1 43 52	956·8	J.	0·271	8·097	
				1·35	1 32 52			0·271	8·094	
				1·40	1 23 10			0·271	8·101	
		H 12	D 5	1·05	3 29 19	1215·9	O.	0·287	8·134	
				1·10	3 02 01			0·287	8·137	
				1·15	2 39 05			0·287	8·133	
				1·20	2 20 03			0·287	8·133	
				1·25	2 03 53			0·287	8·135	
				1·30	1 50 11			0·287	8·134	
				1·35	1 38 23			0·287	8·134	
				1·40	1 28 10			0·287	8·137	
		H 12	A 7	1·10	3 28 27	867·7		0·332	8·100	
				1·15	3 02 36			0·332	8·106	
				1·20	2 40 30			0·331	8·112	
				1·25	2 22 05			0·331	8·114	
				1·30	2 06 25			0·331	8·115	
				1·35	1 52 58			0·331	8·115	
				1·40	1 41 18			0·331	8·117	
				1·45	1 31 08			0·331	8·122	
		H 12	A 8	0·95	3 22 25	1085·3		0·307	8·131	
				1·00	2 53 22			0·307	8·140	
				1·05	2 30 02			0·307	8·138	
				1·10	2 10 29			0·307	8·141	
				1·15	1 54 20			0·307	8·139	
				1·20	1 40 47			0·307	8·136	
				1·25	1 29 11			0·307	8·137	
				1·30	1 19 22			0·307	8·135	
7.		H 12	A 9	1·05	3 43 17	886·7		0·308	8·096	
				1·10	3 14 20			0·308	8·099	
				1·15	2 50 04			0·308	8·103	
				1·20	2 29 48			0·308	8·104	
				1·25	2 12 36			0·308	8·092	
				1·30	1 57 52			0·308	8·097	
				1·35	1 45 17			0·308	8·100	
				1·40	1 34 28			0·308	8·100	
		H 12	A 10	1·05	3 16 05	956·8		0·271	8·096	
				1·10	2 50 36			0·271	8·101	
				1·15	2 29 29			0·271	8·100	
				1·20	2 11 23			0·271	8·101	
				1·25	1 56 37			0·271	8·100	
				1·30	1 43 42			0·271	8·103	
				1·35	1 32 40			0·271	8·102	
				1·40	1 23 08			0·271	8·102	
21.		H 11	D 5	1·25	2 04 18	1215·5	I.	0·287	8·130	
				1·30	1 50 31			0·287	8·131	
				1·35	1 38 42			0·287	8·130	
				1·40	1 28 32			0·287	8·129	
		H 11	A 7	1·30	2 06 46	868·7		0·331	8·108	
				1·35	1 53 19			0·331	8·106	
				1·40	1 41 37			0·331	8·106	
				1·45	1 31 31			0·331	8·105	
		H 11	A 8	1·15	1 54 59	1085·4		0·308	8·110	
				1·20	1 41 22			0·308	8·110	
				1·25	1 29 45			0·308	8·110	
				1·30	1 19 46			0·308	8·111	
		H 11	A 9	1·25	2 13 34	886·8		0·308	8·100	
				1·30	1 58 40			0·308	8·104	
				1·35	1 46 10			0·309	8·098	
				1·40	1 35 11			0·308	8·098	
22.		H 11	A 10	1·25	1 57 13	957·7		0·271	8·102	
				1·30	1 44 14			0·271	8·102	
				1·35	1 33 06			0·271	8·102	
				1·40	1 23 31			0·271	8·101	
		B.	D 5	1·05	3 29 05	1215·5	J.	0·287	8·136	
				1·10	3 01 51			0·287	8·135	
				1·15	2 39 07			0·287	8·136	
				1·20	2 22 35			0·287	8·134	
				1·25	2 04 02			0·287	8·134	
				1·30	1 50 19			0·287	8·136	
				1·35	1 38 33			0·287	8·132	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Dec. 22.	Singapore.	B.	D 5	1·40	° ′ ″ 1 28 20	1515·5	J.	0·287	8·133	
		B.	A 7	1·10	3 27 52	868·7		0·331	8·103	
				1·15	3 02 08			0·331	8·103	
				1·20	2 40 18			0·331	8·108	
				1·25	2 22 04			0·331	8·106	
				1·30	2 06 17			0·331	8·110	
				1·35	1 52 49			0·331	8·111	
				1·40	1 41 10			0·330	8·114	
				1·45	1 31 08			0·330	8·113	
		B.	A 8	0·95	3 22 43	1085·4		0·308	8·121	
				1·00	2 54 02			0·308	8·121	
				1·05	2 30 22			0·308	8·124	
				1·10	2 11 01			0·308	8·111	
				1·15	1 54 45			0·308	8·120	
				1·20	1 41 10			0·308	8·115	
				1·25	1 29 31			0·308	8·118	
				1·30	1 19 34			0·308	8·121	
23.		B.	A 9	1·05	3 42 48	886·8		0·308	8·104	
				1·10	3 13 55			0·308	8·106	
				1·15	2 49 55			0·308	8·105	
				1·20	2 29 34			0·308	8·109	
				1·25	2 12 27			0·308	8·095	
				1·30	1 57 47			0·308	8·099	
				1·35	1 45 14			0·308	8·100	
				1·40	1 34 32			0·308	8·096	
		B.	A 10	1·05	3 16 08	957·7		0·271	8·089	
				1·10	2 50 38			0·271	8·094	
				1·15	2 29 25			0·271	8·096	
				1·20	2 11 42			0·271	8·095	
				1·25	1 56 28			0·271	8·099	
				1·30	1 43 49			0·271	8·092	
				1·35	1 32 42			0·271	8·095	
				1·40	1 23 10			0·271	8·095	
13.		H 12	D 5	1·05	3 28 55	1214·9	O.	0·287	8·136	
				1·10	3 01 41			0·287	8·138	
				1·15	2 38 55			0·287	8·142	
				1·20	2 19 53			0·287	8·142	
				1·25	2 03 47			0·287	8·142	
				1·30	1 50 02			0·287	8·143	
				1·35	1 38 11			0·287	8·147	
				1·40	1 28 04			0·287	8·146	
22.		H 12	A 7	1·10	3 28 03	867·1		0·332	8·111	
				1·15	3 02 04			0·331	8·117	
				1·20	2 40 05			0·331	8·126	
				1·25	2 21 40			0·331	8·129	
				1·30	2 05 59			0·331	8·132	
				1·35	1 52 40			0·331	8·129	
				1·40	1 40 59			0·331	8·133	
				1·45	1 30 55			0·331	8·134	
		H 12	A 8	0·95	3 22 30	1084·3		0·308	8·132	
				1·00	2 53 38			0·308	8·136	
				1·05	2 29 53			0·308	8·144	
				1·10	2 10 39			0·288	8·138	
				1·15	1 54 25			0·308	8·138	
				1·20	1 40 41			0·308	8·142	
				1·25	1 29 11			0·308	8·141	
				1·30	1 19 17			0·308	8·141	
20.		H 12	A 9	1·05	3 43 20	884·5		0·309	8·112	
				1·10	3 14 26			0·309	8·113	
				1·15	2 50 08			0·309	8·118	
				1·20	2 29 46			0·309	8·121	
				1·25	2 12 31			0·309	8·111	
				1·30	1 57 54			0·309	8·112	
				1·35	1 45 26			0·309	8·110	
				1·40	1 34 28			0·309	8·116	
		H 12	A 10	1·05	3 16 45	955·7		0·272	8·094	
				1·10	2 51 13			0·272	8·098	
				1·15	2 29 48			0·272	8·104	
				1·20	2 11 59			0·271	8·104	
				1·25	1 56 53			0·271	8·103	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Dec. 20.	Singapore.	H 12	A 10	1·30	1 43 46	955·7	O.	0·271	8·112	
				1·35	1 32 49			0·271	8·115	
				1·40	1 23 05			0·271	8·117	8·114
1846.										
Jan. 20.	Pulo Peesang.	H 11	D 5	1·25	2 18 01	1156·25	L.	0·319	8·099	
				1·30	2 02 40			0·319	8·101	
				1·35	1 49 32			0·319	8·102	
				1·40	1 38 12			0·319	8·103	
		H 11	D 6	1·25	2 13 14	1170·6		0·307	8·087	
				1·30	1 58 21			0·307	8·091	
				1·35	1 45 38			0·307	8·094	
				1·40	1 34 52			0·307	8·089	
		H 11	A 6	1·20	2 15 48	945·5		0·279	8·106	
				1·40	1 25 52			0·279	8·096	
		H 11	A 7	1·30	2 16 44	839·0		0·355	8·088	
				1·40	1 49 35			0·356	8·088	
		H 11	A 8	1·15	2 09 31	1027·3		0·234	8·109	
				1·40	1 12 01			0·234	8·107	
		H 11	A 9	1·30	2 08 02	856·1		0·332	8·082	
				1·40	1 42 38			0·332	8·078	
		H 11	A 10	1·25	2 16 08	891·6		0·314	8·074	
				1·40	1 37 01			0·314	8·074	8·092
	29. Carimon ...	H 11	D 5	1·25	2 18 47	1158·2		0·319	8·061	
				1·30	2 03 06			0·319	8·071	
				1·35	1 49 50			0·319	8·075	
				1·40	1 38 31			0·319	8·075	
		H 11	D 6	1·25	2 13 22	1170·0		0·307	8·080	
				1·30	1 58 45			0·308	8·073	
				1·35	1 46 02			0·308	8·076	
		H 11	A 6	1·20	2 15 30	947·6		0·278	8·097	
				1·40	1 25 23			0·278	8·101	
		H 11	A 7	1·30	2 16 30	839·7		0·355	8·086	
				1·40	1 49 20			0·355	8·088	
		H 11	A 10	1·25	2 16 21	891·6		0·315	8·054	
				1·40	1 37 10			0·315	8·054	
		H 11	A 9	1·30	2 04 07	868·2		0·332	8·081	
				1·40	1 39 33			0·333	8·076	8·077
	Feb. 22. Lingin	H 11	A 9	1·30	2 04 54	868·5		0·322	8·066	
				1·40	1 40 07			0·322	8·063	
		H 11	D 5	1·25	2 18 28	1159·7		0·318	8·064	
				1·30	2 03 17			0·318	8·059	
				1·35	1 50 00			0·318	8·064	
				1·40	1 38 22			0·318	8·075	
		H 11	D 6	1·25	2 13 51	1171		0·307	8·060	
				1·30	1 58 56			0·307	8·063	
				1·35	1 46 02			0·307	8·070	
				1·40	1 35 14			0·307	8·064	
		H 11	A 6	1·20	2 15 41	949·2		0·278	8·072	
				1·40	1 25 37			0·278	8·070	
		H 11	A 7	1·30	2 16 56	840·8		0·355	8·060	
				1·40	1 49 43			0·355	8·060	
		H 11	A 10	1·25	2 16 58	891·7		0·315	8·037	
				1·40	1 37 32			0·315	8·040	8·062
	June 24. Sarawak ...	H 11	D 6	1·25	2 09 52	1169·3		0·303	8·192	
				1·30	1 55 14			0·302	8·211	
				1·35	1 42 56			0·303	8·201	
				1·40	1 32 20			0·303	8·201	
		H 11	D 5	1·25	2 14 39	1157·6		0·315	8·193	
				1·30	1 59 45			0·315	8·192	
				1·35	1 46 50			0·314	8·197	
				1·40	1 35 54			0·315	8·193	
		H 11	A 6	1·40	1 23 05	949·7		0·273	8·196	
		H 11	A 7	1·30	2 13 45	838·2		0·352	8·190	
				1·40	1 47 10			0·352	8·190	
	30.	H 11	A 8	1·15	2 07 04	1026·9		0·232	8·183	
				1·40	1 10 34			0·232	8·187	
	July 3.	H 11	A 9	1·30	2 02 11	888·9		0·320	8·180	
		H 11		1·40	1 37 55			0·320	8·178	
		H 11	D 5	1·25	2 15 07	1158·6		0·315	8·180	
				1·30	1 59 56			0·314	8·187	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1846.						seconds.				
July 3.	Sarawak ...	H 11	D 5	1·35	1 47 08	1158·6	L.	0·314	8·186	
				1·40	1 36 02			0·314	8·189	
		H 11	D 6	1·25	2 09 45	1171·5		0·302	8·192	
				1·30	1 55 23			0·302	8·192	
				1·35	1 42 59			0·302	8·192	
				1·40	1 32 21			0·302	8·195	
		H 11	A 6	1·20	2 11 53	949·7		0·273	8·198	
				1·40	1 23 09			0·273	8·200	
		H 11	A 7	1·30	2 13 40	839·1		0·351	8·197	
		H 11	A 10	1·25	2 13 14	890·1		0·311	8·172	
				1·40	1 34 56			0·311	8·173	
		H 11	A 9	1·30	2 09 25	865·6		0·320	8·174	
				1·35	1 49 26			0·320	8·171	
				1·40	1 38 05			0·320	8·173	
				1·45	1 28 18			0·320	8·174	
		H 11	A 6	1·20	2 11 59	949·7		0·273	8·189	
				1·25	1 56 53			0·273	8·187	
				1·40	1 23 46			0·274	8·161	
				1·45	1 14 59			0·273	8·187	
		H 11	A 7	1·30	2 13 50	839·1		0·352	8·175	
				1·35	1 59 35			0·352	8·174	
				1·40	1 47 11			0·352	8·177	
				1·45	1 36 35			0·352	8·171	
		H 11	A 8	1·15	2 06 31	1028·0		0·231	8·193	
				1·40	1 10 19			0·231	8·193	
				1·45	1 03 27			0·232	8·184	8·186
	Sept. 17. Batavia ...	H 11	D 5	1·25	2 18 44	1182·2		0·313	7·896	
				1·30	2 03 18			0·313	7·898	
				1·35	1 50 08			0·313	7·898	
				1·40	1 39 28			0·314	7·870	
		H 11	D 6	1·25	2 13 09	1197·4		0·300	7·900	
				1·30	1 58 18			0·300	7·904	
				1·35	1 45 28			0·300	7·901	
				1·40	1 34 34			0·300	7·909	
		H 11	A 6	1·20	2 15 51	968·9		0·272	7·907	
				1·25	2 00 18			0·272	7·903	
				1·30	1 46 56			0·272	7·908	
				1·40	1 35 25			0·272	7·912	
		H 11	A 7	1·30	2 17 23	856·5		0·350	7·900	
				1·35	2 02 44			0·350	7·900	
				1·40	1 50 12			0·350	7·895	
				1·45	1 39 05			0·350	7·901	
		H 11	A 10	1·25	2 18 04	907·1		0·311	7·881	
				1·30	2 02 38			0·311	7·886	
				1·35	1 49 37			0·311	7·884	
				1·40	1 38 24			0·311	7·881	
		H 11	A 9	1·30	2 05 17	884·5		0·318	7·895	
				1·35	1 52 11			0·318	7·885	
				1·40	1 40 47			0·319	7·878	
				1·45	1 30 40			0·318	7·880	
		H 12	D 5	1·25	2 18 56	1182·2		0·312	7·922	
				1·30	2 03 26			0·312	7·924	
		H 11	D 5	1·35	1 50 17			0·312	7·922	
				1·40	1 38 54			0·312	7·922	
	23.		D 6	1·25	2 13 26	1197·4		0·300	7·913	
				1·30	1 58 30			0·300	7·909	
				1·35	1 45 49			0·300	7·909	
				1·40	1 34 51			0·300	7·910	
	Nov. 10.	H 11	D 5	1·25	2 18 08	1186·7		0·310	7·885	
				1·30	2 02 46			0·310	7·890	
				1·35	1 49 37			0·310	7·888	
				1·40	1 38 14			0·310	7·892	
		H 11	D 6	1·25	2 12 55	1200·9		0·298	7·887	
				1·30	1 58 10			0·298	7·889	
				1·35	1 45 30			0·298	7·889	
				1·40	1 34 29			0·298	7·895	
		H 11	A 7	1·30	2 16 53	859·6		0·347	7·878	
				1·35	2 02 24			0·347	7·875	
				1·40	1 49 48			0·347	7·874	
				1·45	1 38 55			0·347	7·871	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Disc. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1846.						seconds.				
Nov. 10.	Batavia ...	H 11	A 8	1·15	2 06 39	1049·5	L.	0·229	7·915	
				1·20	1 54 05			0·229	7·920	
				1·25	1 41 03			0·229	7·918	
				1·30	1 29 44			0·229	7·925	
		H 11	A 10	1·25	2 17 36	908·3		0·310	7·871	
				1·30	2 02 28			0·310	7·868	
				1·35	1 49 20			0·310	7·871	
				1·40	1 38 02			0·310	7·872	
		H 11	A 9	1·30	2 05 57	882·7		0·319	7·891	
				1·35	1 52 13			0·319	7·901	
				1·40	1 40 52			0·319	7·892	
				1·45	1 30 49			0·319	7·891	
1847.										
July 3.		H 11	D 5	1·25	2 12 43	1209·6		0·298	7·899	
				1·30	1 57 56			0·298	7·901	
				1·35	1 45 22			0·298	7·899	
				1·40	1 34 29			0·298	7·899	
		H 11	D 6	1·25	2 07 07	1223·7		0·286	7·920	
				1·30	1 53 12			0·286	7·914	
				1·35	1 41 08			0·286	7·912	
				1·40	1 30 46			0·286	7·908	
		H 11	A 7	1·30	2 13 46	867·6		0·339	7·900	
				1·35	1 59 34			0·340	7·898	
				1·40	1 47 14			0·340	7·898	
				1·45	1 36 35			0·340	7·896	
		H 11	A 8	1·15	2 06 13	1066·0		0·222	7·894	
				1·20	1 51 04			0·222	7·894	
				1·25	1 38 22			0·222	7·892	
				1·30	1 27 29			0·222	7·894	
		H 11	A 9	1·30	2 03 56	890·9		0·314	7·906	
				1·35	1 50 43			0·314	7·905	
				1·40	1 39 15			0·314	7·907	
				1·45	1 29 23			0·314	7·905	
	4.	H 11	D 5	1·25	2 12 44	1209·6		0·298	7·899	
				1·30	1 57 56			0·298	7·901	
				1·35	1 45 19			0·298	7·901	
				1·40	1 34 26			0·298	7·901	
		H 11	D 6	1·25	2 07 33	1223·7		0·286	7·907	
				1·30	1 53 22			0·286	7·908	
				1·35	1 41 10			0·286	7·911	
				1·40	1 30 41			0·286	7·912	
		H 11	A 7	1·30	2 13 56	867·6		0·340	7·896	
				1·35	2 59 37			0·340	7·897	
				1·40	1 47 15			0·340	7·898	
				1·45	1 36 38			0·340	7·895	
		H 11	A 8	1·15	2 06 22	1066·0		0·223	7·885	
				1·20	1 51 13			0·222	7·889	
				1·25	1 38 30			0·222	7·887	
				1·30	1 27 31			0·222	7·893	
		H 11	A 9	1·30	2 04 06	890·9		0·314	7·901	
				1·35	1 50 50			0·314	7·902	
				1·40	1 39 26			0·314	7·901	
				1·45	1 29 32			0·314	7·899	
	6.	H 11	D 5	1·25	2 12 33	1209·6		0·298	7·904	
				1·30	1 57 48			0·298	7·905	
				1·35	1 45 11			0·298	7·906	
				1·40	1 34 15			0·298	7·909	
		H 11	D 6	1·25	2 07 19	1223·7		0·286	7·914	
				1·30	1 53 13			0·286	7·913	
				1·35	1 41 02			0·286	7·916	
				1·40	1 30 34			0·286	7·917	
		H 11	A 7	1·30	2 13 37	867·6		0·339	7·904	
				1·35	1 59 26			0·339	7·903	
				1·40	1 47 06			0·339	7·903	
				1·45	1 36 26			0·339	7·903	
		H 11	A 8	1·15	2 06 05	1066·0		0·222	7·894	
				1·20	1 50 54			0·222	7·901	
				1·25	1 38 21			0·222	7·894	
				1·30	1 27 28			0·222	7·896	
		H 11	A 9	1·30	2 03 58	890·9		0·314	7·906	
1847.										
July 6.	Batavia ...	H 11	A 9	1·35	1 50 39	890·9	L.	0·314	7·908	
				1·40	1 39 20			0·314	7·904	
				1·45	1 29 26			0·314	7·903	
		H 11	D 5	1·25	2 12 41	1209·6		0·298	7·901	
				1·30	1 57 53			0·298	7·900	
				1·40	1 34 25			0·298	7·902	
		H 11	D 6	1·25	2 07 21	1223·7		0·286	7·913	
				1·30	1 52 13			0·286	7·914	
				1·35	1 41 06			0·286	7·914	
				1·40	1 30 42			0·286	7·911	
		H 11	A 7	1·30	2 13 50	867·6		0·340	7·899	
				1·35	1 59 38			0·340	7·897	
				1·40	1 47 18			0·340	7·897	
				1·45	1 36 33			0·340	7·899	
	9.	H 11	A 8	1·15	2 06 15	1066·0		0·222	7·888	
				1·20	1 51 05			0·222	7·893	
				1·25	1 38 28			0·222	7·889	
				1·30	1 27 35			0·222	7·890	
		H 11	A 9	1·30	2 04 31	890·9		0·315	7·889	
				1·35	1 50 49			0·314	7·902	
				1·40	1 39 24			0·314	7·901	
				1·45	1 29 31			0·314	7·899	
	10.	H 11	D 5	1·25	2 13 13	1209·6		0·298	7·898	
				1·30	1 58 26			0·298	7·896	
				1·35	1 45 41			0·298	7·889	
				1·40	1 34 50			0·298	7·886	
		H 11	D 6	1·25	2 07 50	1223·7		0·287	7·898	
				1·30	1 53 50			0·287	7·892	
				1·35	1 41 37			0·287	7·894	
				1·40	1 31 03			0·287	7·896	
		H 11	A 7	1·30	2 14 16	867·6		0·340	7·886	
				1·35	1 59 55			0·340	7·887	
				1·40	1 47 40			0·340	7·883	
				1·45	1 36 49			0·340	7·888	
		H 11	A 8	1·15	2 06 29	1066·0		0·222	7·881	
				1·20	1 51 53			0·222	7·883	
				1·25	1 38 40			0·222	7·886	
				1·30	1 27 34			0·222	7·891	
		H 11	A 9	1·25	2 20 00	890·9		0·315	7·889	
				1·30	2 04 25			0·315	7·891	
				1·35	1 51 04			0·314	7·893	
				1·40	1 39 39			0·315	7·891	
	Aug. 3.	H 11	D 5	1·25	2 12 54	1209·6		0·298	7·893	
				1·30	1 58 11			0·298	7·893	
				1·35	1 45 26			0·298	7·897	
				1·40	1 34 32			0·298	7·897	
		H 11	D 6	1·25	2 07 27	1223·7		0·286	7·909	
				1·30	1 53 15			0·286	7·919	
				1·35	1 41 11			0·286	7·909	
				1·40	1 30 43			0·286	7·909	
		H 11	A 7	1·30	2 14 17	867·6		0·340	7·883	
				1·35	1 59 52			0·340	7·886	
				1·40	1 47 22			0·340	7·891	
				1·45	1 36 40			0·340	7·891	
		H 11	A 8	1·15	2 05 37	1066·0		0·222	7·907	
				1·20	1 53 38			0·222	7·908	
				1·25	1 37 56			0·221	7·913	
				1·30	1 27 10			0·222	7·907	
		H 11	A 9	1·25	2 19 29	890·9		0·314	7·901	
				1·30	2 03 59			0·314	7·903	
				1·35	1 50 41			0·314	7·906	
				1·40	1 39 18			0·314	7·904	
		H 11	A 10	1·25	2 02 08	963·7		0·275	7·877	
				1·30	1 48 34			0·275	7·879	
				1·35	1 36 58			0·275	7·880	
				1·40	1 26 55			0·275	7·883	
	4.	H 11	D 5	1·25	2 12 48	1209·6		0·298	7·896	
				1·30	1 58 04			0·298	7·896	
				1·35	1 45 24			0·298	7·897	
				1·40	1 34 42			0·298	7·889	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
Aug. 4.	Batavia.	H 11	D 6	1·25	2 07 19	1223·7	L.	0·286	7·913	
				1·30	1 53 12			0·286	7·913	
				1·35	1 41 00			0·286	7·917	
				1·40	1 30 37			0·286	7·914	
		H 11	A 7	1·30	2 13 41	867·6		0·340	7·901	
				1·35	1 59 24			0·339	7·902	
				1·40	1 47 13			0·340	7·897	
				1·45	1 36 33			0·340	7·896	
		H 11	A 8	1·15	2 05 13	1066·0		0·221	7·915	
				1·20	1 50 32			0·221	7·913	
				1·25	1 37 48			0·221	7·920	
				1·30	1 26 59			0·221	7·916	
		H 11	A 9	1·25	2 19 28	890·9		0·314	7·902	
				1·30	2 03 52			0·314	7·907	
				1·35	1 50 39			0·314	7·907	
				1·40	1 39 10			0·314	7·909	
		H 11	A 10	1·25	2 01 56	463·7		0·275	7·883	
				1·30	1 48 30			0·275	7·881	
				1·35	1 36 38			0·274	7·893	
				1·40	1 26 57			0·275	7·881	
6.		H 11	D 5	1·25	2 13 00	1209·6		0·298	7·890	
				1·30	1 58 09			0·298	7·893	
				1·35	1 45 31			0·298	7·891	
				1·40	1 34 37			0·298	7·893	
		H 11	D 6	1·25	2 07 34	1223·7		0·287	7·905	
				1·30	1 53 22			0·286	7·907	
				1·35	1 41 19			0·287	7·904	
				1·40	1 30 45			0·286	7·908	
		H 11	A 7	1·30	2 14 05	867·6		0·340	7·889	
				1·35	1 59 40			0·340	7·894	
				1·40	1 47 19			0·340	7·894	
				1·45	1 36 38			0·340	7·894	
		H 11	A 8	1·15	2 05 44	1066·0		0·222	7·904	
				1·20	1 50 44			0·222	7·905	
				1·25	1 38 05			0·222	7·908	
				1·30	1 27 11			0·222	7·907	
		H 11	A 9	1·25	2 19 51	390·9		0·315	7·891	
				1·30	2 04 19			0·314	7·893	
				1·35	1 51 06			0·315	7·891	
				1·40	1 39 37			0·315	7·892	
		H 11	A 10	1·25	2 02 26	963·7		0·275	7·868	
				1·30	1 48 53			0·275	7·868	
				1·35	1 37 13			0·275	7·871	
				1·40	1 27 10			0·275	7·872	
7.		H 11	D 5	1·25	2 13 04	1209·6		0·298	7·889	
				1·35	1 58 08			0·298	7·894	
				1·40	1 45 32			0·298	7·893	
				1·45	1 34 43			0·298	7·889	
		H 11	D 6	1·25	2 07 47	1223·7		0·287	7·900	
				1·30	1 53 29			0·287	7·904	
				1·35	1 41 25			0·287	7·901	
				1·40	1 30 57			0·287	7·900	
		H 11	A 7	1·30	2 14 08	867·6		0·340	7·890	
				1·35	1 59 47			0·340	7·892	
				1·40	1 47 38			0·340	7·885	
				1·45	1 36 54			0·340	7·885	
		H 11	A 8	1·15	2 05 44	1066·0		0·222	7·905	
				1·20	1 50 40			0·222	7·909	
				1·25	1 38 06			0·222	7·909	
				1·30	1 27 07			0·222	7·912	
		H 11	A 9	1·25	2 19 53	890·9		0·315	7·892	
				1·30	2 04 27			0·315	7·891	
				1·35	1 51 08			0·315	7·890	
				1·40	1 39 37			0·314	7·893	
		H 11	A 10	1·25	2 02 08	963·7		0·275	7·878	
				1·30	1 48 28			0·275	7·884	
				1·35	1 37 09			0·275	7·878	
				1·40	1 26 58			0·275	7·881	
8.		H 11	D 5	1·25	2 12 46	1209·6		0·298	7·898	
				1·30	1 57 54			0·298	7·903	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
Aug. 8.	Batavia ...	H 11	D 5	1·35	1 45 26	1209·6	L.	0·298	7·897	
				1·40	1 34 41			0·298	7·898	
		H 11	D 6	1·25	2 07 37	1223·7		0·287	7·905	
				1·30	1 53 24			0·287	7·907	
				1·35	1 41 18			0·287	7·906	
				1·40	1 30 48			0·286	7·907	
		H 11	A 7	1·30	2 13 56	867·6		0·340	7·895	
				1·35	1 59 39			0·340	7·898	
				1·40	1 47 22			0·340	7·893	
				1·45	1 30 40			0·340	7·902	
		H 11	A 8	1·15	2 05 44	1066·0		0·222	7·904	
				1·20	1 50 42			0·222	7·907	
				1·25	1 37 58			0·221	7·913	
				1·30	1 27 03			0·221	7·914	
		H 11	A 9	1·30	2 03 56	890·9		0·314	7·905	
				1·35	1 50 43			0·314	7·904	
				1·40	1 39 24			0·314	7·900	
		H 11	A 10	1·25	2 02 06	963·7		0·275	7·892	
				1·30	1 48 41			0·275	7·887	
				1·35	1 36 57			0·275	7·892	
				1·40	1 27 07			0·275	7·884	7·897
17.	Lampongs, Sumatra.	H 11	D 5	1·25	2 12 09	1209·1		0·297	7·916	
				1·30	1 57 28			0·297	7·916	
				1·35	1 44 52			0·297	7·917	
				1·40	1 34 08			0·297	7·913	
		H 11	D 6	1·25	2 07 20	1221·7		0·287	7·922	
				1·30	1 53 10			0·287	7·924	
				1·35	1 41 07			0·287	7·921	
				1·40	1 30 41			0·287	7·920	
		H 11	A 7	1·30	2 13 22	867·6		0·339	7·909	
				1·35	1 59 11			0·339	7·908	
				1·40	1 46 50			0·339	7·910	
				1·45	1 36 16			0·339	7·907	
		H 11	A 8	1·15	2 04 36	1067·8		0·220	7·921	
				1·20	1 50 05			0·220	7·909	
				1·25	1 37 28			0·220	7·914	
				1·30	1 26 38			0·220	7·913	
		H 11	A 9	1·25	2 18 58	888·5		0·314	7·936	
				1·30	2 03 35			0·314	7·931	
				1·35	1 50 23			0·314	7·931	
				1·40	1 38 52			0·314	7·936	
		H 11	A 10	1·25	2 01 51	963·7		0·274	7·903	
				1·30	1 48 20			0·274	7·905	
				1·35	1 36 49			0·274	7·902	
				1·40	1 26 52			0·274	7·900	7·916
Sept. 22.	Pulo Bay, near Bencoolen.	H 11	D 5	1·25	2 12 02	1210		0·297	7·916	
				1·30	1 57 19			0·297	7·918	
				1·35	1 44 45			0·297	7·918	
				1·40	1 33 56			0·297	7·918	
		H 11	D 6	1·25	2 07 11	1222·9		0·286	7·923	
				1·30	1 52 59			0·286	7·926	
				1·35	1 40 57			0·286	7·924	
				1·40	1 30 31			0·286	7·924	
		H 11	A 7	1·30	2 13 21	868·7		0·339	7·903	
				1·35	1 58 51			0·338	7·918	
				1·40	1 46 43			0·338	7·908	
				1·45	1 36 03			0·338	7·909	
		H 11	A 8	1·15	2 04 34	1069·3		0·220	7·914	
				1·30	1 49 39			0·220	7·918	
				1·25	1 37 19			0·220	7·912	
				1·30	1 26 20			0·220	7·919	
		H 11	A 9	1·25	2 18 43	892·3		0·313	7·909	
				1·30	2 03 13			0·312	7·914	
				1·35	1 50 07			0·312	7·912	
				1·40	1 38 41			0·312	7·912	
		H 11	A 10	1·25	2 01 30	964·2		0·274	7·905	
				1·30	1 48 13			0·274	7·899	
				1·35	1 36 34			0·274	7·902	
				1·40	1 26 40			0·274	7·899	7·913
Oct. 16.	Padang ...	H 11	D 5	1·25	2 10 59	1207·5		0·296	7·960	

Table G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
Oct. 16.	Padang, Sumatra.	H 11	D 5	1·30	1 56 27	1207·5	L.	0·296	7·960	
				1·35	1 44 02			0·297	7·958	
				1·40	1 33 16			0·297	7·959	
		H 11	D 6	1·25	2 06 14	1223·5		0·285	7·946	
				1·30	1 52 14			0·285	7·946	
				1·35	1 40 14			0·285	7·945	
				1·40	1 29 52			0·285	7·945	
		H 11	A 7	1·30	2 12 39	864·8		0·339	7·955	
				1·35	1 58 39			0·339	7·950	
				1·40	1 46 11			0·339	7·959	
				1·45	1 35 46			0·339	7·952	
		H 11	A 8	1·15	2 03 24	1069·7		0·219	7·946	
				1·20	1 48 35			0·219	7·951	
				1·25	1 36 10			0·219	7·954	
				1·30	1 25 35			0·219	7·958	
		H 11	A 9	1·25	2 16 59	888·4		0·312	7·990	
				1·30	2 01 49			0·312	7·990	
				1·35	1 48 56			0·312	7·985	
				1·40	1 37 38			0·312	7·987	
		H 11	A 10	1·25	2 00 34	959·2		0·274	7·975	
				1·30	1 47 05			0·274	7·980	
				1·35	1 35 42			0·274	7·978	
				1·40	1 25 52			0·274	7·975	7·962
1848.										
Mar. 28.	Mount Ophir, near Malacca.	H 11	D 5	1·25	2 04 29	1194·3		0·292	8·273	
				1·30	1 50 37			0·292	8·275	
				1·35	1 38 48			0·292	8·274	
				1·40	1 28 31			0·292	8·278	
		H 11	A 7	1·25	2 06 54	856·7		0·334	8·217	
				1·30	1 53 23			0·334	8·217	
				1·35	1 41 35			0·334	8·221	
				1·40	1 31 31			0·334	8·218	
		H 11	A 8	1·15	1 57 23	1056·3		0·216	8·274	
				1·20	1 43 20			0·216	8·277	
				1·25	1 31 26			0·216	8·285	
				1·30	1 21 23			0·216	8·286	
		H 11	A 9	1·25	2 13 05	874·2		0·312	8·230	
				1·30	1 58 08			0·311	8·237	
				1·35	1 45 34			0·311	8·235	
				1·40	1 34 40			0·311	8·235	
		H 11	A 10	1·25	1 56 44	940·5		0·275	8·270	
				1·30	1 43 41			0·275	8·275	
				1·35	1 33 01			0·275	8·257	
				1·40	1 23 16			0·275	8·264	8·255
May 8.	Pulo Laboan.	H 11	D 5	1·25	2 04 28	1197·5		0·292	8·247	
				1·30	1 50 40			0·292	8·247	
				1·35	1 38 43			0·292	8·247	
				1·40	1 28 38			0·292	8·246	
		H 11	A 7	1·30	2 06 05	857·7		0·334	8·236	
				1·35	1 52 38			0·334	8·232	
				1·40	1 41 03			0·334	8·235	
				1·45	1 30 59			0·334	8·235	
		H 11	A 8	1·15	1 54 41	1071·3		0·211	8·246	
				1·20	1 41 00			0·211	8·248	
				1·25	1 29 28			0·211	8·251	
				1·30	1 19 26			0·211	8·254	
		H 11	A 9	1·25	2 11 52	878·3		0·310	8·232	
				1·30	1 57 14			0·310	8·234	
				1·35	1 44 42			0·310	8·234	
				1·40	1 33 56			0·310	8·232	
		H 11	A 10	1·25	1 55 49	947·7		0·272	8·242	
				1·30	1 42 56			0·272	8·244	
				1·35	1 32 10			0·272	8·234	
				1·40	1 22 46			0·273	8·228	8·240
	29. Samboanga, Island of Mindanão.	H 11	D 5	1·25	2 05 56	1207·7		0·291	8·130	
				1·30	1 51 52			0·291	8·133	
				1·35	1 39 52			0·291	8·135	
				1·40	1 29 34			0·291	8·134	
		H 11	A 7	1·30	2 07 26	863·7		0·333	8·131	
				1·35	1 53 55			0·333	8·129	
1848.										
May 29.	Samboanga, Island of Mindanão.	H 11	A 7	1·40	1 40 09	863·7	L.	0·333	8·129	
				1·45	1 31 59			0·333	8·129	
		H 11	A 8	1·15	1 55 54	1078·0		0·211	8·149	
				1·20	1 42 04			0·211	8·150	
				1·25	1 30 22			0·210	8·155	
				1·30	1 20 16			0·210	8·157	
		H 11	A 9	1·25	2 13 40	881·6		0·310	8·146	
				1·30	1 58 56			0·310	8·144	
				1·35	1 46 13			0·310	8·144	
				1·40	1 35 17			0·210	8·143	
		H 11	A 10	1·25	1 57 29	952		0·273	8·147	
				1·30	1 44 39			0·273	8·147	
				1·35	1 33 28			0·273	8·141	
				1·40	1 23 43			0·273	8·145	
	30.	B.	D 5	1·25	2 04 34	1207·7	J.	0·289	8·167	
				1·30	1 50 27			0·289	8·177	
				1·35	1 38 58			0·290	8·166	
				1·40	1 28 41			0·289	8·168	
			A 7	1·30	2 06 45	863·7		0·332	8·157	
				1·35	1 52 57			0·331	8·166	
				1·40	1 41 40			0·332	8·153	
				1·45	1 31 34			0·322	8·153	
			A 8	0·95	3 23 38	1078·0		0·210	8·176	
				1·00	2 54 52			0·210	8·175	
				1·05	2 31 04			0·210	8·170	
				1·10	2 11 33			0·210	8·179	
				1·15	1 55 13			0·210	8·177	
				1·20	1 41 31			0·210	8·176	
				1·25	1 29 53			0·210	8·175	
				1·30	1 19 55			0·210	8·176	
			A 7	1·10	3 38 19	863·7		0·331	8·169	
				1·15	3 02 33			0·331	8·165	
				1·20	2 40 44			0·331	8·165	
				1·25	2 22 18			0·332	8·165	
			D 5	1·05	3 29 52	1207·7		0·289	8·167	
				1·10	3 02 30			0·289	8·170	
				1·15	2 39 47			0·289	8·170	
				1·20	2 20 37			0·289	8·174	
			A 9	1·05	3 41 45	881·60		0·309	8·174	
				1·10	3 13 05			0·309	8·175	
				1·15	2 49 04			0·309	8·177	
				1·20	2 28 48			0·309	8·181	
			A 9	1·25	2 11 43			0·309	8·181	
				1·30	1 57 06			0·309	8·185	
				1·35	1 44 44			0·309	8·181	
				1·40	1 34 07			0·309	8·174	
			A 10	1·05	3 14 34	952		0·272	8·174	
				1·10	2 49 24			0·272	8·176	
				1·15	2 28 25			0·272	8·176	
				1·20	2 10 43			0·272	8·178	
				1·25	1 55 52			0·272	8·173	
				1·30	1 42 45			0·271	8·187	
				1·35	1 32 02			0·272	8·177	
				1·40	1 22 37			0·272	8·175	8·162
June 21.	Keemah, Island of Celebes.	H 11	D 5	1·25	2 03 29	1199·5		0·290	8·263	
				1·30	1 49 43			0·290	8·266	
				1·35	1 38 01			0·290	8·264	
				1·40	1 27 50			0·290	8·266	
			B.	D 5	1·05	3 28 13		0·290	8·254	
				1·10	3 01 08			0·290	8·255	
				1·15	2 38 25			0·290	8·260	
				1·20	2 19 42			0·290	8·252	
				1·25	2 03 40			0·290	8·250	
				1·30	1 49 50			0·290	8·255	
				1·35	1 38 10			0·290	8·252	
				1·40	1 28 00			0·290	8·253	
		H 11	A 7	1·30	2 05 35	857·7	L.	0·333	8·249	
				1·35	1 52 08			0·333	8·252	
				1·40	1 40 42			0·333	8·246	
				1·45	1 30 35			0·333	8·250	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
June 21.	Keemah, Island of Celebes.	H 11	A 7	1·10	3 26 01	857·7	J.	0·333	8·257	
				1·15	3 00 27			0·332	8·258	
				1·20	2 38 37			0·332	8·270	
				1·25	2 20 42			0·333	8·258	
				1·30	2 05 07			0·332	8·258	
				1·35	1 51 38			0·332	8·259	
				1·40	1 40 28			0·332	8·245	
				1·45	1 30 22			0·332	8·250	
22.		H 11	A 8	0·95	3 20 34	1076·4		0·210	8·282	
				1·00	2 52 15			0·210	8·281	
				1·05	2 28 49			0·210	8·285	
				1·10	2 09 36			0·210	8·283	
				1·15	1 53 32			0·210	8·282	
				1·20	1 40 00			0·210	8·281	
				1·25	1 28 29			0·210	8·283	
				1·30	1 18 43			0·210	8·282	
		H 11	A 9	1·05	3 41 04	876·1		0·311	8·236	
				1·10	3 12 32			0·311	8·236	
				1·15	2 48 41			0·311	8·236	
				1·20	2 28 25			0·310	8·242	
				1·25	2 11 33			0·311	8·236	
				1·30	1 56 53			0·310	8·243	
				1·35	1 44 28			0·310	8·241	
				1·40	1 33 40			0·310	8·240	
		H 11	A 10	1·05	3 14 40	946·3		0·274	8·218	
				1·10	2 49 26			0·273	8·221	
				1·15	2 28 29			0·273	8·221	
				1·20	2 10 41			0·273	8·225	
				1·25	1 55 44			0·273	8·224	
				1·30	1 43 01			0·273	8·222	
				1·35	1 31 57			0·273	8·227	
				1·40	1 22 32			0·273	8·225	
		H 11	A 8	1·15	1 53 45	1071·4	L.	0·210	8·269	
				1·20	1 40 10			0·210	8·271	
				1·25	1 28 40			0·210	8·273	
				1·30	1 19 08			0·210	8·259	
		H 11	A 9	1·25	2 11 55	876·1		0·310	8·251	
				1·30	1 57 20			0·310	8·250	
				1·35	1 44 49			0·310	8·250	
				1·40	1 34 02			0·310	8·248	
		H 11	A 10	1·25	1 55 27	946·3		0·272	8·265	
				1·30	1 42 42			0·272	8·264	
				1·35	1 31 40			0·272	8·267	
				1·40	1 22 26			0·272	8·255	8·253
Aug. 29.	Cocos or Keeling Islands.	H 11	D 5	1·25	2 19 22	1279·1		0·289	7·293	
				1·30	2 03 48			0·289	7·296	
				1·35	1 50 34			0·289	7·295	
				1·40	1 39 16			0·289	7·291	
		H 11	A 7	1·30	2 21 55	914·0		0·332	7·276	
				1·35	2 06 45			0·332	7·277	
				1·40	1 53 43			0·332	7·276	
				1·45	1 42 25			0·332	7·275	
		H 11	A 8	1·15	2 09 16	1141·8		0·210	7·281	
				1·20	1 53 52			0·210	7·281	
				1·25	1 40 48			0·210	7·282	
				1·30	1 29 29			0·210	7·290	
		H 11	A 9	1·25	2 28 23	933·3		0·309	7·300	
				1·30	2 12 06			0·309	7·296	
				1·35	1 58 08			0·309	7·292	
				1·40	1 46 05			0·309	7·287	
		H 11	A 10	1·25	2 11 33	1007·5		0·273	7·272	
				1·30	1 56 59			0·273	7·272	
				1·35	1 44 24			0·272	7·275	
				1·40	1 33 37			0·272	7·275	
		B.	D 5	1·05	3 55 27	1279·1	J.	0·289	7·279	
				1·10	3 24 50			0·289	7·280	
				1·15	2 59 16			0·289	7·281	
				1·20	2 37 38			0·289	7·286	
				1·25	2 19 40			0·289	7·281	
				1·30	2 04 09			0·289	7·282	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Aug. 29.	Cocos or Keeling Islands.	B.	D 5	1·35	1 50 53	1279·1	J.	0·289	7·284	
				1·40	1 39 23			0·289	7·284	
			A 7	1·10	3 54 13	914·0		0·332	7·265	
				1·15	3 25 14			0·332	7·265	
				1·20	3 00 41			0·332	7·265	
				1·25	2 39 47			0·332	7·270	
				1·30	2 22 08			0·332	7·274	
				1·35	2 07 00			0·332	7·274	
				1·40	1 53 57			0·332	7·272	
				1·45	1 42 33			0·332	7·274	
			A 8	0·95	3 47 34	1141·8		0·210	7·298	
				1·00	3 15 27			0·210	7·295	
				1·05	2 49 04			0·210	7·295	
				1·10	2 27 11			0·210	7·295	
				1·15	2 08 56			0·210	7·295	
				1·20	1 53 30			0·210	7·296	
				1·25	1 40 28			0·210	7·299	
				1·30	1 29 31			0·210	7·290	
21.			A 9	1·05	4 10 36	933·3		0·310	7·261	
				1·10	3 38 16			0·310	7·261	
				1·15	3 11 11			0·310	7·262	
				1·20	2 48 22			0·310	7·263	
				1·25	2 29 04			0·311	7·252	
				1·30	2 12 46			0·311	7·250	
				1·35	1 58 26			0·311	7·257	
				1·40	1 46 21			0·311	7·254	
			A 10	1·05	3 40 46	1007·5		0·273	7·251	
				1·10	3 12 14			0·273	7·252	
				1·15	2 48 22			0·273	7·254	
				1·20	2 28 16			0·273	7·256	
				1·25	2 11 23			0·273	7·253	
				1·30	1 56 41			0·273	7·260	
				1·35	1 44 21			0·273	7·256	
				1·40	1 33 38			0·273	7·256	
Sept. 12.		H 11	D 5	1·25	2 19 23	1279·1	I.	0·289	7·296	
				1·30	2 03 38			0·289	7·304	
				1·35	1 50 36			0·289	7·298	
				1·40	1 39 13			0·289	7·296	
		B.	D 5	1·05	3 55 27		J.	0·289	7·280	
				1·10	3 25 00			0·289	7·278	
				1·15	2 59 23			0·289	7·280	
				1·20	2 37 44			0·289	7·285	
				1·25	2 19 22			0·289	7·290	
				1·30	2 04 08			0·289	7·284	
				1·35	1 50 49			0·289	7·286	
				1·40	1 39 27			0·289	7·283	
			A 7	1·10	3 53 31	915·5		0·331	7·271	
				1·15	3 24 36			0·331	7·270	
				1·20	3 00 11			0·331	7·270	
				1·25	2 39 28			0·331	7·271	
				1·30	2 21 56			0·331	7·269	
				1·35	2 06 49			0·332	7·269	
				1·40	1 53 46			0·332	7·268	
				1·45	1 42 27			0·332	7·268	
13.		H 11	A 7	1·30	2 21 40	915·5	I.	0·331	7·278	
				1·35	2 06 33			0·331	7·279	
				1·40	1 53 32			0·331	7·278	
				1·45	1 42 16			0·331	7·276	
		H 11	A 8	1·15	2 08 56	1143·1		0·209	7·284	
				1·20	1 53 30			0·209	7·287	
				1·25	1 40 28			0·209	7·289	
				1·30	1 29 22			0·209	7·289	
14.		H 11	A 9	1·30	2 12 26	933·8		0·309	7·287	
				1·35	1 58 25			0·309	7·282	
				1·40	1 46 08			0·309	7·285	
				1·45	1 35 34			0·309	7·284	
		H 11	A 10	1·25	2 10 57	1009·5		0·271	7·276	
				1·30	1 56 25			0·271	7·278	
				1·35	1 44 01			0·271	7·277	
				1·40	1 33 19			0·271	7·275	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1848.						seconds.				
Sept. 14.	Cocos or Keeling Islands.	B.	A 8	0·95	3 47 59	1143·1	J.	0·209	7·282	
				1·00	3 15 45			0·209	7·278	
				1·05	2 49 18			0·209	7·281	
				1·10	2 27 24			0·209	7·281	
				1·15	2 09 02			0·209	7·282	
				1·20	1 53 36			0·209	7·284	
				1·25	1 40 40			0·209	7·280	
				1·30	1 29 34			0·279	7·279	
			A 9	1·05	4 10 24	933·8		0·310	7·263	
				1·10	3 38 11			0·310	7·262	
				1·15	3 11 05			0·310	7·263	
				1·20	2 48 17			0·310	7·264	
				1·25	2 29 05			0·310	7·251	
				1·30	1 12 35			0·310	7·253	
				1·35	1 58 22			0·310	7·258	
				1·40	1 46 15			0·310	7·257	
			A 10	1·05	3 40 29	1009·5		0·273	7·241	
				1·10	3 12 02			0·273	7·241	
				1·15	2 48 12			0·273	7·242	
				1·20	2 28 06			0·273	7·245	
				1·25	2 11 05			0·273	7·246	
				1·30	1 56 38			0·273	7·247	
				1·35	1 44 13			0·273	7·247	
				1·40	1 33 31			0·273	7·246	7·2745
1849.										
Jan. 12.	Pulo Dinding.	H 11	D 5	1·25	2 04 34	1214·9	I.	0·288	8·125	
				1·30	1 50 39			0·288	8·129	
				1·35	1 38 49			0·288	8·128	
				1·40	1 28 32			0·287	8·131	
		H 11	A 7	1·30	2 06 53	867·8		0·330	8·103	
				1·35	1 53 20			0·330	8·104	
				1·40	1 41 33			0·330	8·104	
				1·45	1 31 30			0·330	8·104	
		H 11	A 8	1·15	1 55 25	1084·7		0·209	8·114	
				1·20	1 41 36			0·209	8·118	
				1·25	1 29 52			0·209	8·132	
				1·30	1 29 32			0·209	8·126	
		H 11	A 9	1·25	2 13 22	886·5		0·308	8·113	
				1·30	1 58 43			0·308	8·109	
				1·35	1 46 01			0·308	8·110	
				1·40	1 35 04			0·308	8·110	
		H 11	A 10	1·25	1 57 17	956·1		0·271	8·118	
				1·30	1 44 16			0·271	8·119	
				1·35	1 33 11			0·271	8·117	
				1·40	1 23 32			0·271	8·118	8·117
Feb. 9.	CarNicobar, Bay of Bengal.	H 11	D 5	1·25	2 03 29	1212·6		0·286	8·178	
				1·30	1 49 43			0·286	8·182	
				1·35	1 37 56			0·286	8·183	
				1·40	1 27 55			0·286	8·177	
		H 11	A 7	1·30	2 05 38	866·7		0·329	8·152	
				1·35	1 52 18			0·329	8·150	
				1·40	1 40 41			0·329	8·151	
				1·45	1 30 43			0·329	8·148	
		H 11	A 8	1·15	1 54 48	1083·6		0·209	8·135	
				1·20	1 41 19			0·209	8·134	
				1·25	1 29 37			0·209	8·139	
				1·30	1 18 32			0·208	8·148	
		H 11	A 9	1·25	2 12 52	885·8		0·308	8·131	
				1·30	1 58 04			0·308	8·132	
				1·35	1 45 29			0·308	8·131	
				1·40	1 34 39			0·308	8·129	
		6. B.	D 5	1·05	3 27 49	1212·6	J.	0·287	8·178	
				1·10	3 00 50			0·287	8·177	
				1·15	2 38 11			0·287	8·180	
				1·20	2 19 17			0·287	8·180	
				1·25	2 03 17			0·287	8·179	
				1·30	1 49 43			0·287	8·175	
				1·35	1 37 51			0·287	8·181	
				1·40	1 27 53			0·287	8·174	
			A 7	1·10	3 26 56	866·7		0·329	8·154	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1849.						seconds.				
Feb. 6.	CarNicobar, Bay of Bengal.	B.	A 7	1·15	3 01 19	866·7	J.	0·329	8·152	
				1·20	2 39 30			0·329	8·157	
				1·25	2 21 20			0·329	8·153	
				1·30	2 05 46			0·329	8·151	
				1·35	1 52 20			0·329	8·151	
				1·40	1 40 46			0·329	8·151	
				1·45	1 30 51			0·329	8·145	
		B.	A 8	0·95	3 21 30	1083·6		0·208	8·176	
				1·00	2 52 50			0·208	8·176	
				1·05	2 29 30			0·208	8·175	
				1·10	2 10 14			0·208	8·172	
				1·15	1 54 04			0·208	8·172	
				1·20	1 40 28			0·208	8·172	
				1·25	1 29 00			0·208	8·169	
				1·30	1 19 09			0·208	8·169	
		B.	A 9	1·05	3 41 28	885·8		0·307	8·139	
				1·10	3 12 46			0·307	8·141	
				1·15	2 48 46			0·307	8·149	
				1·20	2 28 47			0·307	8·141	
				1·25	2 11 41			0·307	8·146	
				1·30	1 57 10			0·307	8·144	
				1·35	1 44 28			0·307	8·156	
				1·40	1 34 01			0·307	8·143	
			A 10	1·05	3 15 19	955·1		0·271	8·147	
				1·10	2 50 11			0·271	8·143	
				1·15	2 29 06			0·271	8·142	
				1·20	2 11 13			0·271	8·146	
				1·25	1 56 12			0·271	8·144	
				1·30	1 43 22			0·271	8·144	
				1·35	1 32 25			0·271	8·141	
				1·40	1 22 48			0·271	8·145	
8.		H 11	A 10	1·25	1 56 34	955·1	I.	0·271	8·145	
				1·30	1 43 35			0·270	8·150	
				1·35	1 32 32			0·270	8·150	
				1·40	1 22 45			0·270	8·160	8·1555
Jan. 25.	Pulo Penang	H 11	D 5	1·25	2 03 19	1214·2		0·286	8·173	
				1·30	1 49 33			0·286	8·176	
				1·35	1 37 43			0·286	8·180	
				1·40	1 27 44			0·286	8·175	
		H 11	A 7	1·30	2 05 41	867·0		0·329	8·148	
				1·35	1 52 20			0·329	8·147	
				1·40	1 40 45			0·329	8·146	
				1·45	1 30 39			0·329	8·150	
		H 11	A 8	1·15	1 54 07	1083·9		0·208	8·163	
				1·20	1 40 33			0·208	8·162	
				1·25	1 29 00			0·208	8·164	
				1·30	1 19 07			0·208	8·167	
		H 11	A 9	1·25	2 12 08	885·6		0·307	8·154	
				1·30	1 57 26			0·307	8·155	
				1·35	1 44 51			0·307	8·157	
				1·40	1 34 04			0·307	8·155	
		H 11	A 10	1·25	1 56 32	954·7		0·271	8·151	
				1·30	1 43 37			0·271	8·152	
				1·35	1 32 31			0·271	8·153	
				1·40	1 22 58			0·271	8·153	8·159
Mar. 27.	Hastings' Island.	H 11	D 5	1·25	2 03 15	1212·3		0·287	8·191	
				1·30	1 49 32			0·287	8·191	
				1·35	1 37 44			0·286	8·195	
				1·40	1 27 42			0·287	8·192	
		H 11	A 7	1·30	2 05 09	866·1		0·329	8·177	
				1·35	1 51 43			0·329	8·180	
				1·40	1 40 18			0·329	8·176	
				1·45	1 30 16			0·329	8·177	
		H 11	A 8	1·15	1 53 53	1083·1		0·208	8·180	
				1·20	1 40 13			0·208	8·186	
				1·25	1 23 48			0·208	8·183	
				1·30	1 19 05			0·208	8·178	
		H 11	A 9	1·25	2 11 48	885		0·3069	8·169	
				1·30	1 57 16			0·3070	8·167	
				1·35	1 44 43			0·3069	8·168	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1849.						seconds.				
Mar. 27.	Hastings' Island.	H 11	A 9	1·40	1 33 59	835	I.	0·3071	8·164	
		H 11	A 10	1·25	1 56 10	954·2		0·270	8·168	
				1·30	1 43 17			0·270	8·169	
				1·35	1 32 17			0·270	8·168	
				1·40	1 22 48			0·270	8·165	8·1772
April 16.	Moulmein.	H 11	D 5	1·25	2 03 19	1220·6		0·285	8·124	
				1·30	1 49 24			0·284	8·133	
				1·35	1 37 43			0·285	8·132	
				1·40	1 27 42			0·285	8·128	
		H 11	A 7	1·30	2 05 41	871·3		0·328	8·100	
				1·35	1 52 09			0·328	8·105	
				1·40	1 40 41			0·328	8·101	
				1·45	1 30 43			0·328	8·097	
		H 11	A 8	1·15	1 54 19	1087·6		0·208	8·130	
				1·20	1 40 43			0·208	8·130	
				1·25	1 29 04			0·208	8·135	
				1·30	1 19 13			0·208	8·135	
		H 11	A 9	1·25	2 11 53	888·2		0·306	8·135	
				1·30	1 57 14			0·306	8·137	
				1·35	1 44 43			0·306	8·137	
				1·40	1 33 43			0·306	8·145	
		H 11	A 10	1·25	1 56 29	959·5		0·269	8·107	
				1·30	1 43 35			0·269	8·108	
				1·35	1 32 26			0·270	8·111	
				1·40	1 23 02			0·270	8·104	
17.		B.	D 5	1·05	3 27 56	1220·6	J.	0·285	8·122	
				1·10	3 00 48			0·285	8·125	
				1·15	2 38 34			0·285	8·121	
				1·20	2 19 22			0·285	8·124	
				1·25	2 03 24			0·285	8·121	
				1·30	1 49 42			0·285	8·122	
				1·35	1 37 59			0·285	8·122	
				1·40	1 27 52			0·285	8·122	
			A 7	1·10	3 26 28	871·3		0·327	8·111	
				1·15	3 00 54			0·327	8·109	
				1·20	2 39 30			0·328	8·105	
				1·25	2 21 16			0·328	8·103	
				1·30	2 05 34			0·328	8·105	
				1·35	1 52 14			0·328	8·104	
				1·40	1 40 19			0·328	8·104	
18.			A 8	0·95	2 22 19	1087·6		0·208	8·134	
				1·00	2 53 24			0·207	8·141	
				1·05	2 30 17			0·208	8·132	
				1·10	2 10 46			0·208	8·133	
				1·15	1 54 38			0·208	8·130	
				1·20	1 40 55			0·208	8·131	
				1·25	1 29 19			0·208	8·132	
				1·30	1 19 31			0·208	8·128	
			A 9	1·05	3 41 42	888 2		0·307	8·110	
				1·10	3 12 51			0·307	8·110	
				1·15	2 48 45			0·307	8·120	
				1·20	2 28 46			0·307	8·117	
				1·25	2 11 44			0·307	8·121	
				1·30	1 57 13			0·307	8·120	
				1·35	1 45 00			0·307	8·111	
				1·40	1 33 56			0·307	8·123	
23.			A 10	1·05	3 15 28	959·5		0·270	8·106	
				1·10	2 50 07			0·270	8·108	
				1·15	2 29 03			0·270	8·107	
				1·20	2 11 17			0·270	8·107	
				1·25	1 56 14			0·270	8·106	
				1·30	1 43 26			0·270	8·108	
				1·35	1 32 32			0·270	8·105	
				1·40	1 22 52			0·270	8·105	8·1186
July 4.	Madras.	H 11	D 5	1·25	2 03 40	1228·1	I.	0·283	8·070	
				1·30	1 49 56			0·283	8·066	
				1·35	1 38 13			0·283	8·064	
				1·40	1 28 06			0·283	8·062	
		H 11	A 7	1·30	2 06 55	874·2		0·328	8·060	
				1·35	1 53 25			0·328	8·059	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1849.						seconds.				
July 4.	Madras.	H 11	A 7	1·40	1 41 45	874·2	I.	0·328	8·057	
				1·45	1 31 37			0·328	8·057	
		H 11	D 5	1·25	2 02 34	1229·8		0·281	8·090	
				1·30	1 48 53			0·281	8·092	
				1·35	1 37 09			0·281	8·095	
				1·40	1 27 10			0·281	8·093	
		H 11	A 7	1·30	2 05 20	878·1		0·325	8·076	
				1·35	1 52 00			0·325	8·073	
				1·40	1 40 26			0·325	8·073	
				1·45	1 30 24			0·325	8·074	
		H 11	A 8	1·15	1 53 19	1096·0		0·205	8·093	
31.				1·20	1 39 56			0·205	8·089	
				1·25	1 28 23			0·204	8·094	
				1·30	1 18 32			0·204	8·098	
		H 11	A 9	1·25	2 12 02	891·9		0·305	8·100	
				1·30	1 57 22			0·304	8·100	
				1·35	1 44 50			0·304	8·100	
				1·40	1 34 02			0·304	8·100	
		H 11	A 10	1·25	1 56 19	962·43		0·268	8·092	
				1·30	1 43 26			0·268	8·092	
				1·35	1 32 25			0·268	8·092	
				1·40	1 22 52			0·268	8·092	
Aug. 1.		B.	D 5	1·05	3 26 30	1229·8	J.	0·282	8·083	
				1·10	2 59 37			0·282	8·085	
				1·15	2 37 10			0·282	8·087	
				1·20	2 18 20			0·282	8·088	
				1·25	2 02 31			0·282	8·084	
				1·30	1 48 53			0·282	8·087	
				1·35	1 37 16			0·282	8·085	
				1·40	1 27 10			0·282	8·088	
2.			A 7	1·10	3 26 33	878·1		0·325	8·071	
				1·15	3 00 49			0·325	8·073	
				1·20	2 39 20			0·325	8·071	
				1·25	2 21 05			0·325	8·070	
				1·30	2 05 30			0·325	8·069	
				1·35	1 52 10			0·325	8·068	
				1·40	1 40 33			0·325	8·068	
				1·45	1 30 32			0·325	8·068	
4.			A 8	0·95	3 20 08	1096·0		0·204	8 096	
				1·00	2 51 26			0·204	8·105	
				1·05	2 28 33			0·204	8·101	
				1·10	2 09 13			0·204	8·094	
				1·15	1 53 14			0·204	8·097	
				1·20	1 39 43			0·204	8·098	
				1·25	1 28 19			0·204	8·096	
				1·30	1 18 35			0·204	8·094	
7.		B.	A 9	1·05	3 41 39	891·9		0·305	8·084	
				1·10	3 12 59			0·305	8·084	
				1·15	2 49 01			0·305	8·085	
				1·20	2 28 52			0·305	8·087	
				1·25	2 12 07			0·305	8·075	
				1·30	1 57 20			0·305	8·082	
				1·35	1 44 59			0·305	8·083	
				1·40	1 34 06			0·305	8·082	
		B.	A 10	1·05	3 15 29	962·43		0·268	8·081	
				1·10	2 50 08			0·268	8·082	
				1·15	2 29 05			0·268	8·081	
				1·20	2 10 55			0·268	8·093	
				1·25	1 56 20			0·269	8·077	
				1·30	1 43 30			0·269	8·076	
				1·35	1 32 26			0·269	8·077	
				1·40	1 23 00			0·269	8·073	
Sept. 27.			D 5	1·05	3 26 04	1231·5		0·281	8·085	
				1·10	2 59 12			0·281	8·087	
				1·15	2 36 46			0·281	8·089	
				1·25	2 02 13			0·281	8·086	
				1·30	1 48 40			0·281	8·086	
				1·35	1 37 02			0·281	8·087	
				1·40	1 27 01			0·281	8·087	
28.			A 7	1·10	3 26 03	878·1		0·325	8·075	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1849.						seconds.				
Sept. 28.	Madras.	B.	A 7	1·15	3 00 31	878·1	J.	0·325	8·074	
				1·20	2 38 51			0·325	8·077	
				1·25	2 20 42			0·325	8·075	
				1·30	2 05 07			0·325	8·076	
				1·35	1 51 50			0·325	8·077	
				1·40	1 40 20			0·325	8·072	
				1·45	1 30 22			0·325	8·071	
			A 8	0·95	3 19 26	1099·1		0·204	8·084	
				1·00	2 51 12			0·204	8·082	
				1·05	2 28 03			0·204	8·084	
				1·10	2 08 55			0·204	8·083	
				1·15	1 52 55			0·204	8·082	
				1·20	1 39 34			0·204	8·078	
				1·25	1 28 08			0·204	8·077	
				1·30	1 18 23			0·204	8·077	
			A 9	1·05	3 41 43	895·2		0·304	8·053	
				1·10	3 13 07			0·304	8·053	
				1·15	2 49 07			0·304	8·054	
				1·20	2 29 04			0·304	8·052	
				1·25	2 12 02			0·304	8·050	
				1·30	1 57 18			0·304	8·054	
				1·35	1 44 52			0·304	8·054	
				1·40	1 34 03			0·304	8·053	
			A 10	1·05	3 15 32	963·6		0·268	8·069	
				1·10	2 50 10			0·268	8·071	
				1·15	2 29 04			0·268	8·070	
				1·20	2 11 20			0·268	8·069	
				1·25	1 56 18			0·268	8·068	
				1·30	1 43 29			0·268	8·066	
				1·35	1 32 36			0·269	8·060	
				1·40	1 22 52			0·268	8·069	
Oct. 2.		H 11	D 5	1·25	2 02 10	1231·5	I.	0·281	8·089	
				1·30	1 48 34			0·281	8·090	
				1·35	1 37 05			0·281	8·085	
				1·40	1 26 52			0·281	8·093	
		H 11	A 7	1·30	2 05 01	878·1		0·325	8·077	
				1·35	1 51 39			0·325	8·079	
				1·40	1 40 05			0·325	8·079	
				1·45	1 30 16			0·325	8·074	
		H 11	A 8	1·15	1 53 32	1099·1		0·204	8·055	
				1·20	1 39 46			0·204	8·066	
				1·25	1 28 11			0·204	8·073	
				1·30	1 18 24			0·204	8·075	
		H 11	A 9	1·25	2 11 43	895·2		0·303	8·075	
				1·30	1 57 08			0·303	8·075	
				1·35	1 44 35			0·303	8·076	
				1·40	1 33 52			0·304	8·074	
		H 11	A 10	1·25	1 56 41	963·6		0·268	8·067	
				1·30	1 43 44			0·268	8·068	
				1·35	1 32 35			0·268	8·071	
				1·40	1 23 00			0·268	8·072	8·0784
1845.										
Aug. 14.	Singapore.	C 15	C 7	1·6	3 40 34	1343·41	P.	1·052	7·959	
				2·1	1 37 46			1·052	7·957	
16.				1·6	3 40 46	1343·0		1·052	7·955	
				2·1	1 37 49			1·051	7·961	
18.				1·6	3 40 44	1344·58		1·054	7·948	
				2·1	1 37 40			1·051	7·953	
19.				1·6	3 40 46	1344·91		1·051	7·947	
				2·1	1 37 37			1·050	7·954	
20.				1·6	3 41 31	1344·03		1·053	7·939	
				2·1	1 38 38			1·055	7·922	7·9495
1846.										
Mar. 28.				1·6	3 36 24	1357·70		1·030	7·950	
				1·7	3 00 42			1·030	7·947	
				1·8	2 32 11			1·030	7·949	
				1·9	2 09 38			1·031	7·943	
				2·0	1 51 06			1·030	7·945	
				2·1	1 35 34			1·028	7·963	
				2·2	1 23 34			1·031	7·942	
				2·3	1 12 39			1·027	7·968	7·951
1848.										
Nov. 28.	Singapore.	C 15	C 7	1·6	3 25 57	1387·7	P.	0·978	7·969	
				1·7	2 51 34			0·977	7·975	
				1·8	2 24 25			0·977	7·980	
				1·9	2 03 31			0·978	7·969	
				1·6	3 24 29			0·977	7·996	
				1·7	2 50 24			0·977	8·000	
				1·8	2 33 14			0·977	8·001	
				1·9	2 02 15			0·977	7·997	
Dec. 26.				1·6	3 24 38	1387·2		0·978	7·997	
				1·7	2 50 40			0·978	7·998	
				1·8	2 23 34			0·977	8·006	
				1·9	2 01 59			0·977	8·010	7·991
1846.										
Jan. 21.	Pulo Pee-sang.			1·7	3 00 46	1352·4		1·034	7·962	
				1·8	2 32 00			1·033	7·971	
				2·2	1 23 42			1·035	7·952	
				2·3	1 12 56			1·033	7·970	7·964
30.	Carimon.			1·7	2 59 53	1357·2		1·028	7·961	
				1·8	2 31 16			1·028	7·964	
				2·2	1 23 02			1·028	7·964	
				2·3	1 12 58			1·030	7·948	7·959
Feb. 8.	Pulo Booäya			1·7	3 01 37	1361·3		1·031	7·911	
				1·8	2 33 06			1·031	7·910	
				2·2	1 24 25			1·034	7·887	
				2·3	1 13 18			1·030	7·918	7·907
21.	Lingin.			1·7	3 00 57	1358·8		1·029	7·938	
				1·8	2 32 18			1·028	7·943	
				2·2	1 23 46			1·030	7·930	
				2·3	1 13 09			1·029	7·938	7·937
May 21.	Sarāwak, Borneo.			1·7	2 57 10	1352·8		1·027	8·015	
				1·8	2 28 44			1·023	8·014	
				2·2	1 21 46			1·023	8·011	
				2·3	1 11 07			1·020	8·037	
July 3.				1·7	2 57 26	1356·4		1·026	8·000	
				1·8	2 29 10			1·024	8·013	
				2·2	1 22 00			1·025	8·010	
				2·3	1 12 01			1·026	7·997	
7.				1·7	2 56 40	1355·7		1·026	8·033	
				1·8	2 28 35			1·024	8·044	
				2·2	1 21 45			1·025	8·038	
				2·3	1 11 33			1·025	8·039	8·024
21.	Sambas, Borneo.			1·7	2 56 00	1356·6		1·022	8·017	
				1·8	2 27 48			1·019	8·034	
				2·3	1 10 54			1·020	8·044	8·032
25.	Permangkat at the mouth of the Sambas river.			1·7	2 55 18	1355·8		1·020	8·048	
				1·8	2 27 45			1·020	8·050	
				2·2	1 21 08			1·019	8·052	
				2·3	1 11 14			1·021	8·041	8·048
Aug. 4.	Pontiānak, Borneo.			1·7	2 56 33	1360·7		1·021	7·992	
				1·8	2 29 02			1·021	7·989	
				2·2	1 21 29			1·019	8·008	
				2·3	1 11 52			1·023	7·978	7·992
13.	Succadāna, Borneo.			1·7	2 57 50			1·022	7·948	
				1·8	2 29 24			1·020	7·963	
				2·2	1 22 14			1·021	7·956	
				2·3	1 12 12			1·022	7·945	7·953
Sept. 17.	Batavia, Island of Java.			1·7	3 00 46	1383·9		1·012	7·791	
				1·8	2 32 32			1·013	7·786	
				2·2	1 23 38			1·013	7·785	
				2·3	1 13 12			1·014	7·784	
				1·7	3 01 40			1·014	7·777	
				1·8	2 32 44			1·013	7·786	
				2·2	1 24 02			1·016	7·763	
				2·3	1 13 25			1·014	7·779	
				1·7	3 00 45	1383·6		1·011	7·785	
				1·8	2 31 58			1·009	7·795	
				2·2	1 23 50			1·013	7·769	
				2·3	1 12 57			1·010	7·792	
1847.										
July 19.				1·7	2 58 16	1395·3		0·995	7·787	

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r', r'', &c.	Exp. of deflec. Angles. a, a', a'', &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
July 19.	Batavia, Island of Java.	C 15	C 7	1·8	S 36 15	1395·3	P.	0·995	7·787	
				2·2	1 22 34			0·996	7·777	
				2·3	1 12 09			0·995	7·783	
				1·7	2 58 04			0·994	7·791	
				1·8	2 29 48			0·993	7·797	
				2·2	1 22 22			0·995	7·785	
				2·3	1 12 17			0·996	7·774	
				1·7	2 59 26			0·997	7·767	
				1·8	2 30 14			0·994	7·791	
				2·2	1 22 47			0·997	7·770	
				2·3	1 12 08			0·995	7·787	
				1·7	2 58 50			0·995	7·786	
				1·8	2 30 39			0·995	7·788	
				2·2	1 22 41			0·995	7·783	
20.				1·7	2 58 43			0·995	7·785	
				1·8	2 30 55			0·995	7·786	
				2·2	1 23 00			0·998	7·764	
				2·3	1 12 16			0·995	7·785	
Aug. 5.				1·6	3 33 31			0·994	7·790	
				1·7	2 58 03			0·994	7·791	
				1·8	2 29 52			0·994	7·797	
				1·9	2 08 05			0·996	7·777	
				1·6	3 33 13			0·994	7·792	
				1·7	2 57 55			0·994	7·790	
				1·8	2 29 53			0·994	7·793	
				1·9	2 07 47			0·995	7·783	7·784
Sept. 29.	Ceram.			1·7	3 02 36	1389·2		1·002	7·725	
				1·8	2 33 59			1·012	7·723	
				2·2	1 24 26			1·012	7·721	
				2·3	1 13 59			1·013	7·716	7·721
Oct. 1.	Anjeer.			1·7	3 01 50	1387·3		1·012	7·757	
				1·8	2 33 08			1·020	7·759	
				2·2	1 24 02			1·012	7·753	
				2·3	1 13 28			1·012	7·757	7·757
	3. Cheringin.			1·7	3 01 16	1387·1		1·010	7·760	
				1·8	2 32 44			1·010	7·761	
				2·2	1 23 47			1·011	7·758	
				2·3	1 13 34			1·024	7·745	7·756
	5. Balembangan.			1·7	3 03 17	1386·1		1·013	7·729	
				1·8	2 34 18			1·012	7·733	
				2·2	1 24 55			1·014	7·717	
				2·3	1 14 10			1·013	7·725	7·726
	6. Chebiliang.			1·7	3 04 31	1397·3		1·014	7·615	
				1·8	2 35 28			1·012	7·634	
				2·2	1 25 33			1·014	7·619	
				2·3	1 14 43			1·013	7·627	7·623
	10. Chelangkahan.			1·7	3 03 33	1385·25		1·012	7·661	
				1·8	2 35 05			1·012	7·658	
				2·2	1 25 09			1·013	7·651	
				2·3	1 15 08			1·017	7·630	7·647
	12. Goonong Dädap.			1·7	3 00 50	1381·7		1·012	7·808	
				1·8	2 31 59			1·012	7·818	
				2·2	1 23 22			1·012	7·816	
				2·3	1 13 03			1·013	7·811	7·813
	15. Woorong Goonong.			1·7	3 01 09	1384·9		1·011	7·782	
				1·8	2 32 07			1·010	7·796	
				2·2	1 23 53			1·013	7·772	
				2·3	1 13 02			1·010	7·793	7·786
Dec. 1.	Chunjür.			1·7	3 00 13	1392·5		1·003	7·754	
				1·8	2 31 46			1·002	7·757	
				2·2	1 23 25			1·004	7·746	
				2·3	1 12 37			1·001	7·767	7·756
	4. Kärang Tengga.			1·7	2 59 38	1387·4		1·004	7·801	
				1·8	2 31 02			1·003	7·810	
				2·2	1 23 04			1·004	7·797	
				2·3	1 12 31			1·003	7·807	7·804
	7. Chebränok.			1·7	2 59 43	1390·0		1 004	7·784	
				1·8	2 30 52			1·002	7·799	
				2·2	1 23 11			1·005	7·776	
				2·3	1 12 40			1·004	7·783	7·786
1846.						seconds.				
Dec. 8.	Palabüan Rätu.	C 15	C 7	1·7	S 59 55	1396·1	P.	1·000	7·744	
				1·8	2 31 37			1·000	7·744	
				2·2	1 23 05			1·000	7·745	
				2·3	1 12 44			1·000	7·744	7·744
	10. Chilotoe.			1·7	3 00 16	1390·6		1·004	7·765	
				1·8	2 31 38			1·003	7·772	
				2·2	1 23 37			1·005	7·757	
				2·3	1 12 34			1·002	7·764	7·764
	12. Pangangbahan.			1·7	2 59 31	1391·30		1·002	7·780	
				1·8	2 31 04			1·001	7·785	
				2·2	1 23 13			1·004	7·766	
				2·3	1 12 37			1·002	7·777	7·777
	13. Mookro Chikasso.			1·7	3 02 24	1397·1		1·005	7·681	
				1·8	2 33 11			1·003	7·694	
				2·3	1 13 31			1·003	7·693	7·689
	15. Sidang Bärang.			1·7	3 01 23	1404·3		0·998	7·659	
				1·8	2 33 01			1·000	7·655	
				2·2	1 24 19			1·001	7·644	7·653
	16. Bejong Petair.			1·7	2 58 17	1391·8		1·000	7·802	
				1·8	2 30 17			1·000	7·801	
				2·2	1 22 38			1·001	7·789	
				2·3	1 12 25			1·002	7·783	7·794
	21. Bandong.			1·7	2 58 56	1387·3		1·002	7·812	
				1·8	2 30 42			1·001	7·814	
				2·2	1 22 32			1·002	7·808	
				2·3	1 12 31			1·003	7·802	7·809
	24. Garoet.			1·7	2 59 14	1389·5		1·002	7·790	
				1·8	2 30 46			1·001	7·798	
				2·2	1 22 50			1·002	7·788	
				2·3	1 12 23			1·001	7·794	7·793
	29. Permangpek			1·7	3 01 24	1400·6		1·000	7·689	
				1·8	2 32 32			0·999	7·698	
				2·2	1 23 33			0·999	7·700	
				2·3	1 13 08			0·999	7·700	7·697
1847.										
Jan. 1.	Cherüg-nüktok.			1·7	2 59 17	1393·7		1·000	7·764	
				1·8	2 30 50			0·999	7·771	
				2·2	1 22 59			1·001	7·756	
				2·3	1 12 29			1·000	7·764	7·764
	6. Kälipoochen.			1·7	2 58 50	1394·0		0·998	7·769	
				1·8	2 30 21			0·997	7·787	
				2·2	1 22 40			0·998	7·775	
				2·3	1 12 18			0·998	7·777	7·777
	10. Chäwee.			1·7	2 58 24	1388·9		0·999	7·827	
				1·8	2 30 18			0·999	7·828	
				2·2	1 22 32			1·000	7·821	
				2·3	1 12 24			1·001	7·812	7·822
	12. Samadang.			1·7	2 58 16	1388·3		1·001	7·817	
				1·8	2 29 40			0·992	7·832	
				2·2	1 22 24			1·001	7·815	
				2·3	1 12 13			1·002	7·809	7·818
	18. Indramäyu.			1·7	2 58 40	1388·1		1·000	7·818	
				1·8	2 30 31			1·000	7·820	
				2·2	1 22 40			1·001	7·811	
				2·3	1 12 16			1·000	7·816	7·813
	26. Tegal.			1·7	2 27 54	1389·9		0·998	7·822	
				1·8	2 29 54			0·998	7·823	
				2·2	1 22 21			0·999	7·813	7·819
	30. Samärang.			1·7	2 58 15	1391·3		0·998	7·807	
				1·8	2 30 01			0·997	7·812	
				2·2	1 22 17			0·998	7·809	
				2·3	1 12 09			0·998	7·802	7·807
Feb. 2.	Japära.			1·7	2 57 43	1387·9		0·999	7·833	
				1·8	2 29 55			0·998	7·842	
				2·2	1 22 05			0·999	7·833	
				2·3	1 12 02			1·001	7·823	7·833
	5. Ambarāwa.			1·7	2 56 38	1393·4		0·991	7·836	
				1·8	2 28 47			0·991	7·838	
				2·2	1 21 50			0·993	7·824	
				2·3	1 11 33			0·992	7·828	7·832

TABLE G.

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
Feb. 13.	Solo.	C 15	C 7	1·7	2 57 50	1389·6	P.	0·998	7·824	
				1·8	2 29 55			0·999	7·823	
				2·2	1 22 03			0·998	7·829	
				2·3	1 11 46			0·998	7·831	7·827
18.	Nyāwee.			1·7	2 56 01	1383·42		0·998	7·909	
				1·8	2 27 59			0·997	7·917	
				2·2	1 21 31			1·000	7·898	
				2·3	1 11 19			0·998	7·909	7·908
22.	Soorabāya.			1·7	2 55 10	1381·91		0·995	7·946	
				1·8	2 27 18			0·994	7·942	
				2·2	1 20 55			0·995	7·933	
				2·3	1 10 55			0·996	7·948	7·942
Mar. 23.	Sumenap.			1·7	2 55 00	1382·3		0·996	7·934	
				1·8	2 27 14			0·996	7·940	
				2·2	1 20 52			0·997	7·932	
				2·3	1 11 02			0·998	7·918	
26.				1·7	2 55 32	1383·6		0·997	7·913	
				1·8	2 27 41			0·996	7·920	
				2·2	1 26 07			0·998	7·902	
				2·3	1 10 58			0·997	7·913	
31.				1·7	2 55 49	1382·9		0·998	7·910	
				1·8	2 28 04			0·996	7·912	
				2·2	1 21 28			1·000	7·897	
				2·3	1 11 18			1·000	7·896	7·916
April 8.	Pulo Kuneeang.			1·7	2 54 37	1382·6		0·996	7·902	
				1·8	2 26 52			0·995	7·946	
				2·2	1 20 39			0·996	7·938	
				2·3	1 10 53			0·998	7·922	
				1·7	2 55 43	1381·3		0·998	7·921	
				1·8	2 27 58			0·998	7·924	
				2·2	1 21 26			1·000	7·908	
				2·3	1 11 22			1·000	7·903	
10.				1·7	2 55 22	1374·75		1·001	7·957	
				1·8	2 27 28			1·000	7·965	
				2·2	1 21 05			1·001	7·953	
				2·3	1 11 08			1·009	7·942	7·932
26.	Bezooki.			1·7	2 56 19	1386·75		0·997	7·880	
				1·8	2 28 39			0·997	7·878	
				2·2	1 21 42			0·998	7·867	
				2·3	1 11 03			0·995	7·892	7·879
May 12.	Kedeeri.			1·7	2 58 14	1395·8		0·995	7·784	
				1·8	2 30 16			0·995	7·782	
				2·2	1 22 31			0·997	7·770	
				2·3	1 12 18			0·997	7·771	
13.				1·7	2 59 02			0·997	7·767	
				1·8	2 30 20			0·995	7·781	
				2·2	1 22 46			0·998	7·763	
				2·3	1 12 07			0·995	7·781	7·775
21.	Patchitan.			1·7	2 58 36	1399·6		0·994	7·756	
				1·8	2 30 07			0·993	7·766	
				2·2	1 22 34			0·995	7·753	
				2·3	1 12 15			0·995	7·754	7·757
June 1.	Manāroo.			1·7	2 56 41	1392·0		0·995	7·831	
				1·8	2 28 38			0·994	7·838	
				2·2	1 21 49			0·996	7·821	
				2·3	1 11 30			0·995	7·827	7·829
6.	Kārang Bolang.			1·7	2 58 02	1396·5		0·997	7·804	
				1·8	2 29 36			0·996	7·815	
				2·2	1 22 25			0·998	7·795	
				2·3	1 11 56			0·997	7·806	7·805
9.	Chilāchap.			1·7	2 58 32	1394·9		0·996	7·791	
				1·8	2 30 07			0·996	7·790	
				2·2	1 22 32			0·997	7·778	
				2·3	1 12 11			0·997	7·781	7·785
25.	Kandang Aur.			1·7	2 57 01	1395·3		0·993	7·814	
				1·8	2 28 49			0·992	7·823	
				2·2	1 22 10			0·993	7·794	
				2·3	1 11 22			0·991	7·824	7·814
Aug. 19.	Lampongs, Sumātra.			1·6	3 32 14	1395·5		0·992	7·808	

Date.	Station.	Magnets employed. Suspended.	Magnets employed. Deflecting.	Exp. of deflec. Dist. r, r′, r″, &c.	Exp. of deflec. Angles. a, a′, a″, &c.	Observed time of 300 vibrations.	Declinometer.	Results. m.	Results. X.	General mean.
1847.						seconds.				
Aug. 19.	Lampongs, Sumātra.	C 15	C 7	1·7	2 57 09	1395·5	P.	0·992	7·805	
				1·8	2 29 06			0·991	7·811	
				1·9	2 07 10			0·993	7·801	7·809
Sept. 1.	Poolo Bay, near Bencoolen.			1·6	3 32 29	1396·6		0·991	7·800	
				1·7	2 57 24			0·991	7·796	
				1·8	2 29 18			0·991	7·802	
				1·9	2 07 42			0·993	7·780	7·794
Oct. 22.	Padang.			1·6	3 39 24	1392·9		0·987	7·867	
				1·7	2 54 50			0·987	7·863	
				1·8	2 27 17			0·987	7·865	
				1·9	2 05 30			0·988	7·857	7·863
1848.										
May 6.	Pulo Laboo-an.			1·6	3 23 50	1376·6		0·985	8·087	
				1·7	2 49 27			0·983	8·101	
				1·8	2 22 58			0·984	8·097	
				1·9	2 01 55			0·985	8·086	8·093
27.	Samboo-anga.			1·6	3 24 22	1386·0		0·980	8·010	
				1·7	2 50 26			0·989	8·011	
				1·8	2 23 33			0·986	8·014	
				1·9	2 02 18			0·981	8·007	8·011
June 21.	Keemah.			1·6	3 21 50	1375·7		0·982	8·121	
				1·7	2 48 16			0·981	8·123	
				1·8	2 21 33			0·980	8·131	
				1·9	2 00 42			0·982	8·126	8·124
Sept. 1.	Cocos or Keeling Islands.			1·6	3 48 51	1469·1		0·982	7·171	
				1·7	3 10 21			0·980	7·182	
				1·8	2 40 37			0·981	7·178	
				1·9	2 16 39			0·981	7·177	
7.				1·6	3 48 06	1465·4		0·979	7·170	
				1·7	3 09 58			0·978	7·176	
				1·8	2 40 07			0·978	7·176	
				1·9	2 16 15			0·978	7·174	
12.				1·6	3 48 31	1465·6		0·980	7·157	
				1·7	3 10 42			0·980	7·156	
				1·8	2 40 57			0·981	7·151	
				1·9	2 16 51			0·981	7·152	7·167
1849.										
Jan. 3.	Malacca.			1·6	3 24 12	1390·68		0·976	7·986	
				1·7	2 50 22			0·976	7·986	
				1·8	2 23 05			0·975	7·999	
				1·9	2 02 01			0·976	7·989	7·981
13.	Pulo Dinding.			1·6	3 24 07	1387·2		0·978	8·012	
				1·7	2 50 05			0·978	8·016	
				1·8	2 23 12			0·977	8·020	
				1·9	2 01 56			0·978	8·011	8·015
27.	Penang.			1·6	3 22 42	1390·0		0·974	8·022	
				1·7	2 49 04			0·973	8·023	
				1·8	2 22 20			0·973	8·027	
				1·9	2 01 17			0·974	8·020	8·024
Feb. 10.	Nicobar.			1·6	3 23 29	1390·2		0·974	8·000	
				1·7	2 49 23			0·973	8·008	
				1·8	2 22 54			0·974	8·004	
				1·9	2 01 49			0·975	7·995	8·002
Mar. 27.	Hastings' Island.			1·6	3 21 35	1386·9		0·973	8·061	
				1·7	2 47 28			0·971	8·077	
				1·8	2 21 18			0·971	8·073	
				1·9	2 00 29			0·972	8·063	8·068
April 16.	Moulmein.			1·6	3 24 51	1391·4		0·976	7·973	
				1·7	2 50 26			0·975	7·983	
				1·8	2 23 40			0·975	7·983	
				1·9	2 02 31			0·976	7·972	7·978
Aug. 25.	Madras.			1·6	3 23 42	1400·3		0·967	7·943	
				1·7	2 49 32			0·966	7·952	
				1·8	2 22 20			0·965	7·968	
				1·9	2 01 21			0·965	7·963	
Oct. 3.				1·6	3 23 02	1402·1		0·965	7·943	
				1·7	2 49 15			0·965	7·946	
				1·8	2 22 30			0·965	7·950	
				1·9	2 01 12			0·965	7·950	7·951

Absolute Determinations of Dip, Horizontal and Total Intensity, and Variation at different Stations in the Archipelago, together with the Heights, in Feet, of some of the Stations in Sumátra determined by Cary's Portable Barometer.

Table H.

Date.	Station.	Latitude.	Longitude.	Dip corrected to Jan. 1, 1848.	Horizontal Intensity.	Total Intensity.	Variation.	Altitude above sea level.
		° ′ ″	° ′ ″	° ′			° ′ ″	
1845	Singapore	1 18 33 N.	103 56 30 E.	.....	8·0947	8·306	1 36 46·6 E.	S. L.*
1846	Singapore	.....	.....	12 51·8 S.	8·121	8·333	.....	S. L.
1847	Singapore	.....	.....	12 56·2	8·116	8·328	.....	S. L.
1848	Singapore	.....	.....	12 56·7	8·114	8·326	1 36 15	S. L.
January, 1846	Pulo Peesang	1 27 52·6	103 19 15	.....	8·092	.....	1 31 07	S. L.
	Carimons	0 59 22	103 27 00	.....	8·077	.....	1 23 05	S. L.
February.	Pulo Booÿa	0 09 09	104 21 00	.....	.....	.....	1 28 49	S. L.
	Lingin	0 11 39 S.	104 37 00	.....	8·062	.....	1 19 07	S. L.
May, June and July.	Saráwak	1 33 54 N.	110 29 00	11 14·9	8·186	8·346	1 09 40	U.†
July.	Sambas	1 22 00	109 28 00	11 31·0	8·166	8·334	1 15 50	U.
July.	Permanket	1 10 29	109 04 15	12 35·8	8·182	8·384	1 09 33	S. L.
August.	Pantiának	0 01 19·3 S.	109 30 00	12 45·0	8·125	8·331	1 31 19	S. L.
August.	Succadána	1 15 33	109 57 00	17 02·1	8·086	8·457	1 22 39	S. L.
September.	Batavia	6 09 52	106 58 00	27 05·4	7·897	8·870	0 47 07	S. L.
September 29.	Ceram	6 07 05	106 15 00	27 14·2	7·850	8·829	0 34 25	S. L.
October 1.	Anjeer	6 02 47	106 01 00	26 32·0	7·887	8·815	0 58 11	S. L.
October 3.	Cheringin	6 22 05	105 46 45	27 34·0	7·886	8·895	0 50 44	S. L.
October 5.	Palambangan	6 31 00	105 54 45	28 08·6	7·855	8·909	0 59 10	U.
October 7.	Chebiliang	6 47 00	105 49 15	28 41·1	7·753	8·834	0 20 36	U.
October 10.	Chelangkahan	6 54 00?	106 06 45?	28 23·9	7·647	8·838	0 13 46	U.
October 12.	Goonong Dádap	6 28 00?	106 06 00?	27 31·7	7·943	8·958	0 52 57	U.
October 15.	Woorong Goonong	6 11 00?	106 10 00?	27 23·2	7·916	8·915	0 40 04	U.
November 23.	Tegu	6 43 04	106 58 45?	28 45·4	.....	.....	0 11 32?	U.‡
November 27.	Pangerango	6 51 00?	106 59 00?	29 45·7	.....	.....	.....	U.§
December 1.	Chunjúr	6 50 08	107 09 45	28 26·1	7·886	8·967	1 35 28?	U.‖
December 4.	Kárang Tengga	6 58 16	106 47 45	28 24·1	7·934	9·020	1 13 18	U.
December 7.	Chebránok	6 57 14	106 25 30	28 30·8	7·916	9·009	0 35 09	S. L.
December 8.	Wyn Cooper's Bay	7 05 00?	106 36 30	29 21·5	7·873	9·033	0 32 20	S. L.
December 10.	Chilotoe	7 11 17	106 27 00	28 54·3	7·894	9·017	0 27 38	U.
December 11.	Pangangbahan	7 30 37	106 19 00	29 44·4	7·907	9·106	0 10 05	U.
December 13.	Mooáro Chikasso	7 28 00	106 38 00	30 08·3	7·817	9·039	0 13 14	S. L.
December 15.	Sidang Bárang	7 30 00?	107 10 00	30 15·0	7·781	9·007	0 05 13	U.
December 16.	Bejong Petair	7 13 36	107 09 00	29 36·5	7·924	9·113	0 16 33	U.
December 21.	Bandong	6 55 44	107 40 30	28 34·4	7·939	9·040	0 26 23	U.
December 24.	Garoet	7 13 54	107 55 00	29 01·5	7·925	9·060	0 25 21	U.
December 29.	Permangpek	7 39 23	107 45 15	30 14·8	7·826	9·059	0 20 20	U.
Jan. 1, 1847	Cherúgnáktok	7 38 25	108 09 45	30 10·9	7·894	9·132	0 18 13	U.
Jan. 6.	Kálipoochen	7 39 02	108 52 30	29 53·9	7·907	9·121	0 57 46	S. L.¶
Jan. 8.	Banjeer	7 23 08	108 42 00	29 09·9	.....	.....	0 27 59	U.
Jan. 10.	Cháwee	7 09 34	108 23 00	28 41·9	7·953	9·066	0 33 23	U.
Jan. 12.	Samadang	6 51 14	108 04 45	28 00·2	7·948	9·002	0 30 24	U.
Jan. 14.	Cheribon	6 43 34	108 42 00	27 52·0	.....	.....	0 31 41	S. L.
Jan. 18.	Indramáyu	6 19 35	108 25 45	27 30·9	7·944	9·057	0 41 05	S. L.
Jan. 26.	Tegal	6 51 57	109 15 30	28 05·1	7·950	9·010	0 37 59	S. L.
Jan. 30.	Samárang	6 59 42	110 30 45	27 04·6	7·937	8·915	0 23 51	S. L.
Feb. 2.	Japara	6 36 07	110 38 15	27 29·9	7·964	8·978	0 24 55	S. L.
Feb. 5.	Ambaráwa	7 16 08	110 28 45	29 27·7	7·963	9·146	0 33 17	U.
Feb. 10.	Balembang	7 24 00?	110 37 00	29 02·4	.....	.....	.....	U.
Feb. 13.	Solo	7 35 00?	110 53 30	29 12·7	7·958	9·118	0 35 59	U.
Feb. 15.	Nyáwee	7 23 52	111 29 15	28 59·9	8·040	9·193	0 29 25	U.
Feb. 22.	Bankáwa, Solo river	7 00 26	112 21 00	27 47·3	8·025	9·072	0 28 38	U.
Feb. 25.	Soorabáya	7 16 01	112 44 30	28 53·0	8·075	9·222	0 51 55	S. L.
March.	Súmenap	7 00 26	113 51 15	27 45·8	8·048	9·096	0 44 15	S. L.
April.	Pulo Kuneeang	6 51 32	115 16 30	27 25·6	8·064	9·086	0 32 07	S. L.
Apr. 26.	Bezooki	7 43 29	113 42 45	27 07·5	8·011	9·000	0 29 59	S. L.
May.	Kedeeri	7 48 39	112 00 00	29 52·2	7·905	9·115	0 28 28	U.
May 21.	Patchitan	8 12 56	111 05 30	30 36·0	7·887	9·163	0 19 32	S. L.
June 1.	Munoori	7 35 22	110 04 00	29 20·5	7·960	9·130	0 18 18	U.
June 6.	Kárang Bolong	7 45 44	109 27 00	29 55·9	7·935	9·157	0 32 13	S. L.
June 9.	Chilácap	7 44 29	108 57 15	29 45·8	7·915	9·118	0 36 57	S. L.
June 12.	Aji Bárang	2 34 49	109 03 30	27 22·1	.....	.....	0 54 38	U.
June 25.	Kandang Aur	6 23 46	108 04 30	.....	7·944	.....	0 18 13	S. L.
August.	Lamponga	5 26 12	105 20 15	26 15·7	7·916	8·827	1 12 30	S. L.
September.	Bencoolen	3 53 54	102 28 45	23 54·0	7·913	8·655	1 05 09	S. L.

* S.L. Sea level. † U.; height unknown. ‡ November 22nd, variation = 10′ 20″ E. and 23rd = 12′ 45″.
§ Pangerango, about 10,000 feet high. ‖ By morning sights 1° 33′ 30″. Afternoon 1° 31′ 17″, and by equal altitudes 1° 35′ 28″.
¶ This variation is different from the others, but by equal altitudes = 0° 57′ 26″ E.

Table H.

Date.	Station.	Latitude.	Longitude.	Dip corrected to Jan. 1, 1848.	Horizontal Intensity.	Total Intensity.	Variation.	Altitude above sea level.
		° ′ ″	° ′ ″	° ′			° ′ ″	
October, 1847	Padang	0 58 58 S.	100 21 15 E.	18 32·2 S.	7·962	8·397	1 24 26 E.	S. L.
Nov. 1 and 2.	Solok	0 47 05	100 55 45	17 50·8	.....	.....	1 39 05	1339
Nov. 5.	Sijonjong	0 41 47	101 19 30	17 49·8	.....	.....	1 21 38	458
Nov. 8.	Bua Pänjäng	0 28 09	101 08 00	17 11·4	.....	.....	1 22 29	U.
Nov. 10.	Päyacombo	0 13 16	101 04 45	16 38·2	.....	.....	1 29 46	1631
Nov. 11.	Fort Vande Capellen	0 27 34	101 03 00	17 12·3	.....	.....	1 28 13	U.
Nov. 14.	Padang Panjang	0 22 00?	100 42 30	17 47 5	.....	.....	1 33 30	2559
Nov. 16.	Fort de Kock	0 13 00?	100 27 15	16 59·6	.....	.....	1 09 23	3043
Nov. 17.	Menindjo	0 13 00	100 14 00	17 00·8	.....	.....	1 31 48	1492
Nov. 18.	Balembangan	0 11 44	100 10 15	16 47·3	.....	.....	1 36 39	2583
Nov. 19.	Peesang	0 07 55	100 12 00	16 33·4	.....	.....	1 46 33	U.
Nov. 20.	Bonjol	0 00 52	100 13 30	16 38·5	.....	.....	1 35 30	650
Nov. 21.	Loobisikapping	0 06 55? N.	.....	16 08·3	.....	.....	.....	1475
Nov. 22.	Batoo Bedindi	0 16 00?	.....	15 49·2	.....	.....	1 35 45	909
Nov. 23.	Lender	0 24 24	100 04 00	15 35·2	.....	.....	.....	895
Nov. 24 and 25.	Rau	0 33 07	99 56 45	15 37·4	.....	.....	1 37 37	848
Nov. 26.	Pionghay	0 36 19	99 52 15	15 50·2	.....	.....	1 38 49	1756
Nov. 27.	Batong	0 39 00	99 47 15	15 41·5	.....	.....	.....	1941
Nov. 28.	Kotanopan	0 42 00	99 42 45	15 19·9	.....	.....	1 34 30	1490
Nov. 29.	Täna Bätoo	0 44 26	99 30 45	15 03·1	.....	.....	.....	1707
Dec. 1.	Fort Elout	0 50 56	99 32 20	14 48·1	.....	.....	1 43 35	680
Dec. 3.	Singalängan	1 14 48	.....	14 11·9	.....	.....	.....	U.
Dec. 6.	Padang Sidompang	1 22 33	99 22 45	13 47·0	.....	.....	.....	928
Dec. 12 to 16.	Sibogha	1 44 42	98 56 15	13 02·5	.....	.....	1 40 38	S. L.
Dec. 19 and 20.	Bäres	2 00 51	98 31 30	12 58·0	.....	.....	1 16 42	S. L.
Dec. 23 to 25.	Sinkel	2 16 37	97 51 35	12 23·5	.....	.....	1 34 08	S. L.
Dec. 31.	Goonong Satoolie, Pulonias	1 17 35	97 40 50	14 05·8	.....	.....	1 43 38	S. L.
Jan. 10 to 13, 1848.	Nätal	0 33 44	99 20 15	15 39·4	.....	.....	1 28 08	S. L.
March 28.	Mount Ophir, near Malácca	2 22 00?	102 38 00?	9 55·1	8·255	8·380	.....	U*.
May 3 to 5.	Pulo Labooan	5 16 59·5	115 18 15	2 51·6	8·240	8·250	1 36 27	S. L.
May 25 and 26.	Sambooanga	6 54 20	122 13 45	1 18·2 N.	8·162	8·164	1 15 24	S. L.
June 21.	Keemah	1 21 55	125 07 59	11 01·4 S.	8·253	8·408	1 39 47	S. L.
June 27.	Tondäno	1 17 31	124 50 11	10 54·3	.....	.....	1 07 37	2240
June 29.	Manädo	1 29 11	124 51 11	10 43·6	.....	.....	1 26 16	S. L.
Aug. and Sept.	Cocos	12 05 38 S.	96 50 30	39 18·5	7·2745	9·400	1 10 42 W.	S. L.
January 2, 1849	Malacca	2 11 19 N.	102 17 00	11 25·2	8·114	8·278	1 50 24 E.	S. L.
Jan. 10.	Pulo Dinding	4 12 47	100 32 52	7 31·2	8·117	8·187	1 48 34	S. L.
Jan. 20.	Pulo Penang	5 25 36	100 24 38	4 52·8	8·159	8·189	1 48 48	S. L.
Feb. 5 to 12.	Nicobar	9 10 12	92 48 23	1 14·8 N.	8·155	8·157	1 53 21	S. L.
Feb. 17.	Noncowry Harbour	8 01 42	93 39 20	0 54·4 S.	.....	.....	.....	U.
Feb. 19.	Bompoko	8 14 05	93 19 20	0 22·9	.....	.....	.....	S. L.
Mar. 26.	Hastings' Island	10 06 45	98 21 15	4 19·0 N.	8·1772	8·200	2 13 10	S. L.
April.	Moulmein	16 29 46	97 45 30	17 45·6	8·1186	8·525	2 20 25	S. L.
July and August.	Madras	13 04 09?	80 16 00	7 34·2	8·0784	8·149	0 56 08	S. L.

* Mount Ophir, about 6000 feet high.

TABLE I.

Observations at Sea.

Abstract of Three Hourly Observations made at Sea.

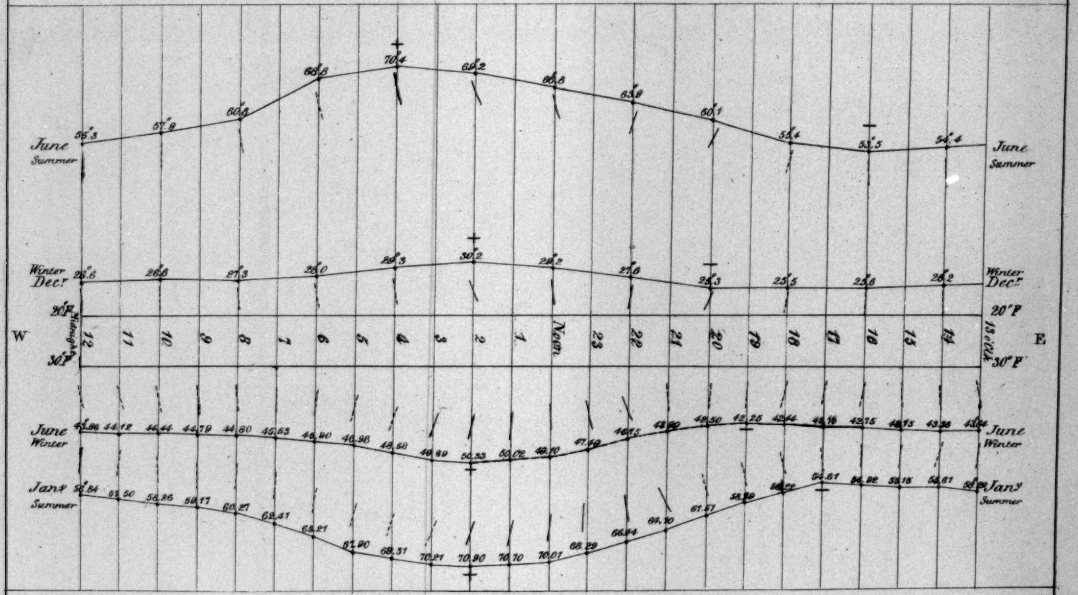
Astronomical Mean Time.	15.	18.	21.	Noon.	3.	6.	9.	Mean.
Observations made during the Month of April, 1848, corresponding to a Mean Latitude of 2° 42′ N.; Mean Longitude 108° 03′ E. Mean date April 27.								
Dry Thermometer, mean of 5 days	83·4	82·7	83·9	86·5	88·3	85·0	84·4	84·9
Wet Thermometer, mean of 5 days	79·5	79·2	79·1	80·5	82·0	79·3	79·8	79·9
Standard Thermometer, mean of 5 days	83·5	83·2	83·6	86·2	88·0	85·4	84·5	85·0
Temperature of the Air, mean of 5 days	.....	83·4	83·8	85·0	86·8	.....	.....	84·8
Temperature of the Sea, mean of 3 days	.....	83·9	84·3	85·8	86·5	.....	.....	85·1
Observations made during the month of May, 1848, corresponding to a Mean Latitude of 7° 07′ N.; Mean Longitude =119° 50′ E. Mean date May 15.								
Dry Thermometer, mean of 12 days	83·1	82·7	84·9	88·1	89·2	86·3	84·6	85·6
Wet Thermometer, mean of 12 days	79·1	78·7	79·5	81·2	82·0	80·3	79·3	80·0
Standard Thermometer, mean of 12 days	83·4	82·6	84·4	87·5	89·5	87·1	85·0	85·7
Temperature of the Air, mean of 10 days	.....	83·2	85·3	87·8	88·1	.....	.....	86·1
Temperature of the Sea, mean of 10 days	.....	85·1	86·1	87·1	87·3	.....	.....	86·4
Observations made during the month of June, 1848, corresponding to a Mean Latitude of 3° 20′ N.; Mean Longitude 125° 00′ E. Mean date June 10.								
Dry Thermometer, mean of 14 days	81·5	81·3	82·8	85·3	85·6	83·9	82·7	83·3
Wet Thermometer, mean of 14 days	77·5	77·7	78·2	79·5	79·5	78·7	77·9	78·4
Standard Thermometer, mean of 14 days	81·8	81·3	82·4	84·9	85·5	84·6	83·1	83·4
Temperature of the Air, mean of 14 days	81·0	81·8	83·4	85·7	85·3	84·2	.....	83·8
Temperature of the Sea, mean of 14 days	82·4	84·1	84·4	85·6	85·2	84·9	.....	84·7
Observations made during the Month of July, 1848, corresponding to a Mean Latitude of 2° 55′ S.; Mean Longitude 126° 00′ E. Mean date July 17.								
Dry Thermometer, mean of 22 days	80·5	80·3	81·5	83·7	83·8	82·3	81·7	82·0
Wet Thermometer, mean of 22 days	77·1	77·4	77·0	78·4	78·3	77·6	77·5	77·6
Standard Thermometer, mean of 22 days	80·5	80·2	81·0	83·9	84·0	82·8	82·1	82·1
Temperature of the Air, mean of 22 days	80·8	80·6	81·6	84·2	84·2	82·8	82·2	82·4
Temperature of the Sea, mean of 22 days	80·7	81·8	82·5	83·7	83·5	82·9	82·1	82·5
Observations made during the Month of August, 1848, corresponding to a Mean Latitude of 6° 32′ S.; Mean Longitude 105° E. Mean date August 17.								
Dry Thermometer, mean of 9 days	79·5	79·0	82·0	84·3	83·3	81·9	80·8	81·6
Wet Thermometer, mean of 9 days	77·4	76·6	77·7	78·6	78·4	77·8	76·8	77·6
Standard Thermometer, mean of 9 days	79·3	78·9	81·5	84·2	83·5	81·9	81·1	81·5
Temperature of the Air, mean of 9 days	80·0	79·3	81·6	84·0	83·3	82·7	81·7	81·8
Temperature of the Sea, mean of 9 days	81·2	82·5	84·6	85·1	84·3	84·8	83·6	83·7

Table I.

Astronomical Mean Time.	15.	18.	21.	Noon.	3.	6.	9.	Mean.
Observations made during the Month of October, 1848, corresponding to a Mean Latitude of 3° 00′ S.; Mean Longitude 103° 00′ E. Mean date October 10.								
Dry Thermometer, mean of 8 days	80·5	80·2	83·1	86·7	86·7	84·0	81·9	83·4
Wet Thermometer, mean of 8 days	77·1	76·4	78·3	80·0	79·7	78·3	77·0	78·2
Standard Thermometer, mean of 8 days	80·5	80·0	82·4	86·1	86·5	84·3	82·4	83·2
Temperature of the Air, mean of 8 days	80·9	80·5	83·9	87·6	87·1	83·2	82·3	83·8
Temperature of the Sea, mean of 8 days	83·4	84·0	84·4	86·2	86·1	84·7	84·6	84·8
Observations made during the Month of November, 1848, corresponding to a Mean Latitude of 0° 46′ N.; Mean Longitude 105° 20′ E. Mean date November 3.								
Dry Thermometer, mean of 4 days	81·4	82·2	81·7	83·1	84·8	83·8	82·4	82·8
Wet Thermometer, mean of 4 days	78·6	78·0	77·1	78·5	79·2	78·5	77·6	78·2
Standard Thermometer, mean of 4 days	81·2	82·0	81·2	82·9	83·9	84·2	82·5	82·5
Temperature of the Air, mean of 4 days	82·1	82·3	82·3	83·5	85·3	84·1	82·2	83·1
Temperature of the Sea, mean of 4 days	83·6	83·0	84·8	85·0	85·1	84·3	83·8	84·3
Observations made during the Month of February, 1849, corresponding to a Mean Latitude of 9° 00′ N.; Mean Longitude 92° 48′ E. Mean date February 20.								
Dry Thermometer, mean of 10 days	80·4	79·9	82·2	84·3	83·5	82·4	81·0	81·9
Wet Thermometer, mean of 10 days	75·8	75·0	75·7	76·9	75·8	75·8	75·4	75·8
Standard Thermometer, mean of 10 days	80·3	79·8	81·5	83·9	83·5	82·7	81·4	81·8
Observations made during the Month of March, 1849, corresponding to a Mean Latitude of 8° 06′; Mean Longitude 97° 34′ E. Mean date March 20.								
Dry Thermometer, mean of 15 days	83·1	82·4	84·4	86·8	87·4	84·8	84·1	84·7
Wet Thermometer, mean of 15 days	78·3	77·9	78·7	79·7	80·4	78·9	78·9	79·0
Standard Thermometer, mean of 15 days	83·0	82·3	83·9	86·3	87·4	85·1	84·0	84·6
Temperature of the Air, mean of 5 days	83·6	83·2	85·0	87·3	88·1	85·6	84·3	85·5
Temperature of the Sea, mean of 5 days	84·5	84·2	84·9	85·6	85·3	84·7	84·5	84·7
Observations made during the Month of April, 1849, corresponding to a Mean Latitude of 12° 25′ N.; Mean Longitude 97° 34′ E. Mean date April 4.								
Dry Thermometer, mean of 6 days	83·0	82·7	84·4	87·7	88·6	86·1	84·4	85·3
Wet Thermometer, mean of 6 days	78·3	78·0	79·3	80·9	81·1	80·3	78·5	79·5
Standard Thermometer, mean of 6 days	83·0	82·6	83·9	87·2	88·2	86·2	84·6	85·1
Temperature of the Air, mean of 6 days	82·6	82·5	85·0	87·1	88·2	85·3	84·5	85·1
Temperature of the Sea, mean of 6 days	84·2	84·8	85·4	86·3	86·3	85·6	84·0	85·3

Fig. 12.

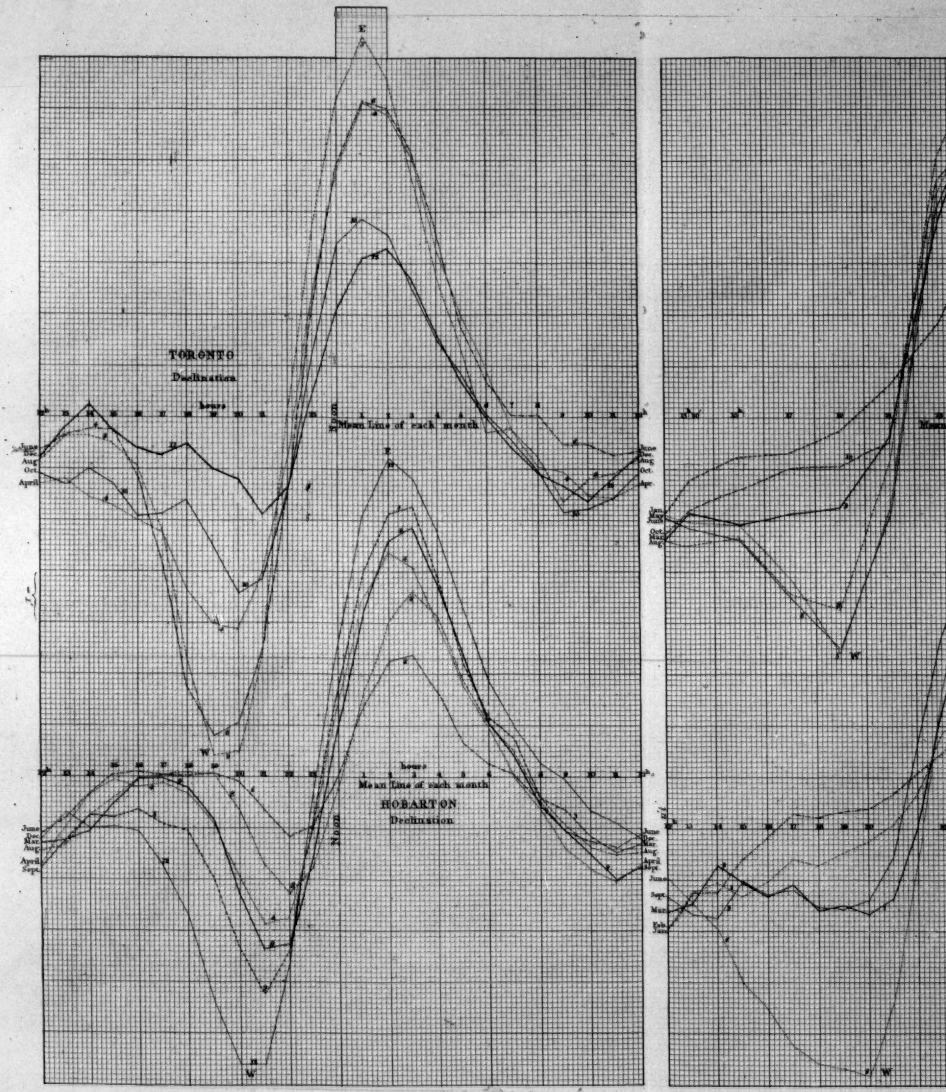
Lat 43° 39' 35" N Toronto Long: 79° 21' 30" W



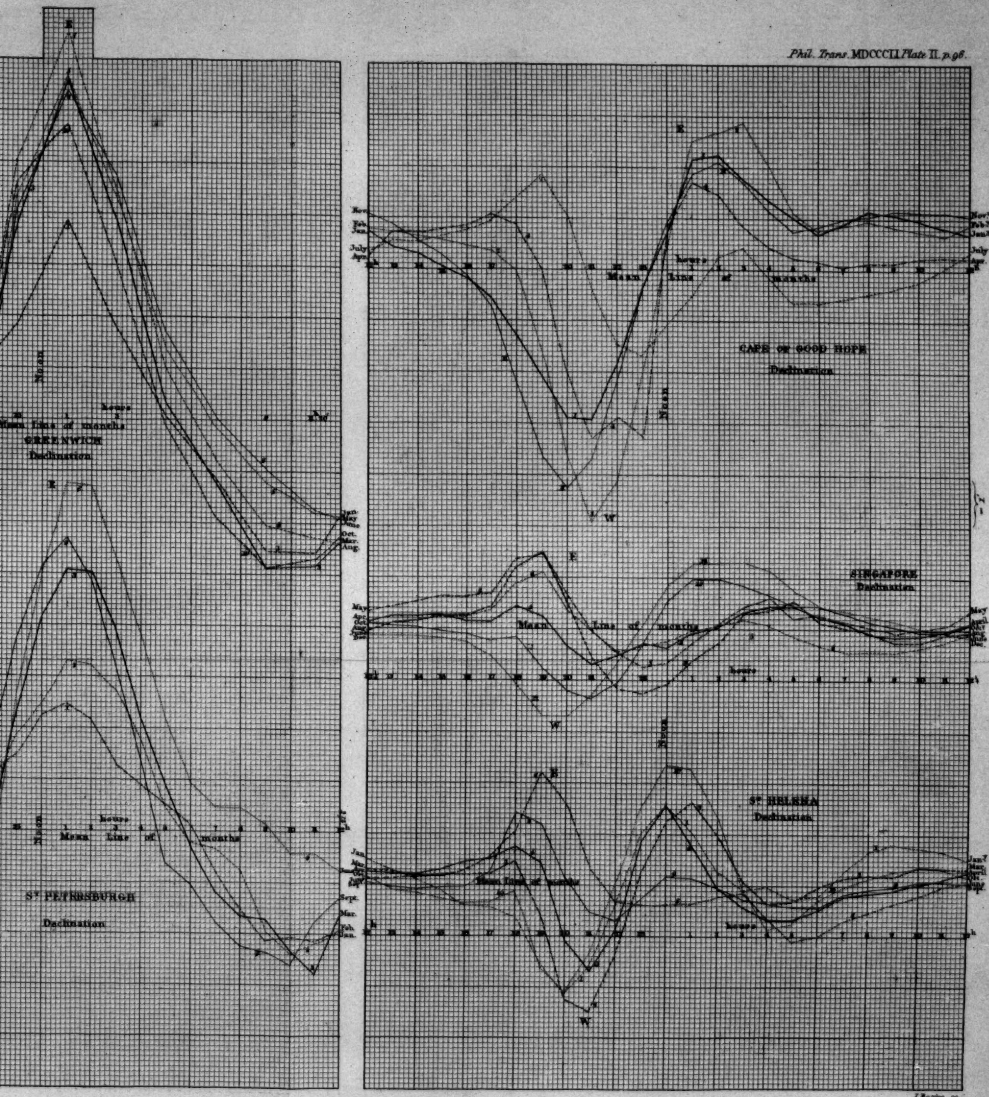
Lat 42° 52' 5 S Hobarton Long: 147° 27' 5 East

Fig. 10.

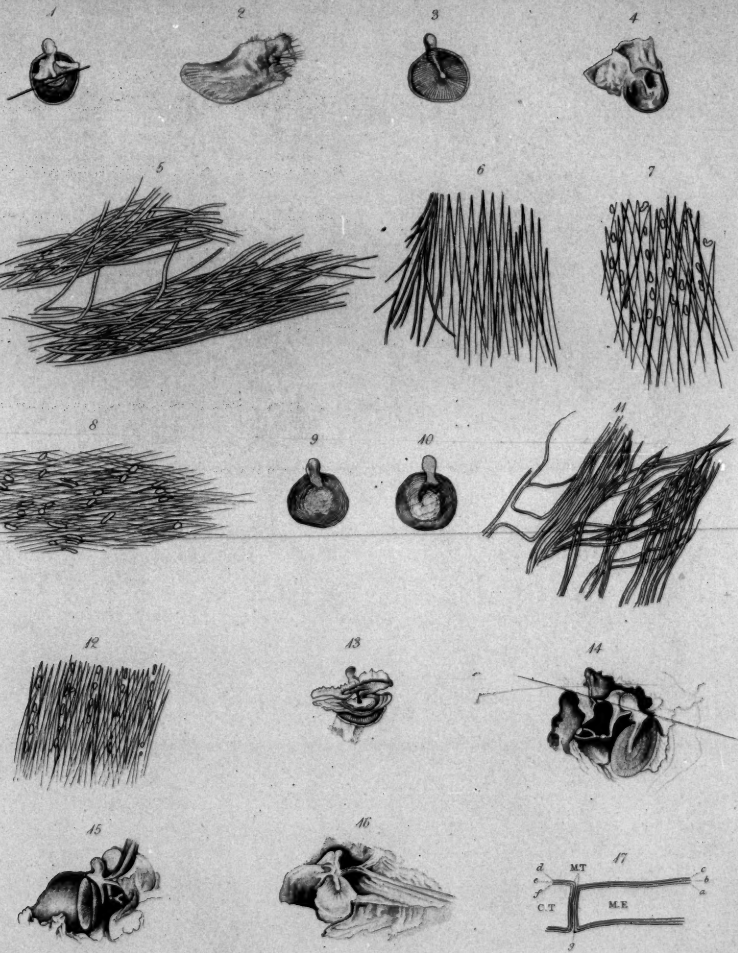
J. Basire, Lith.



Eastern positions of the upper end of a free Needle are indicated when th



the curves are above the Mean Line of the months, and Western positions when below



H.T. del.t

J.Basire sc.

PART 1.

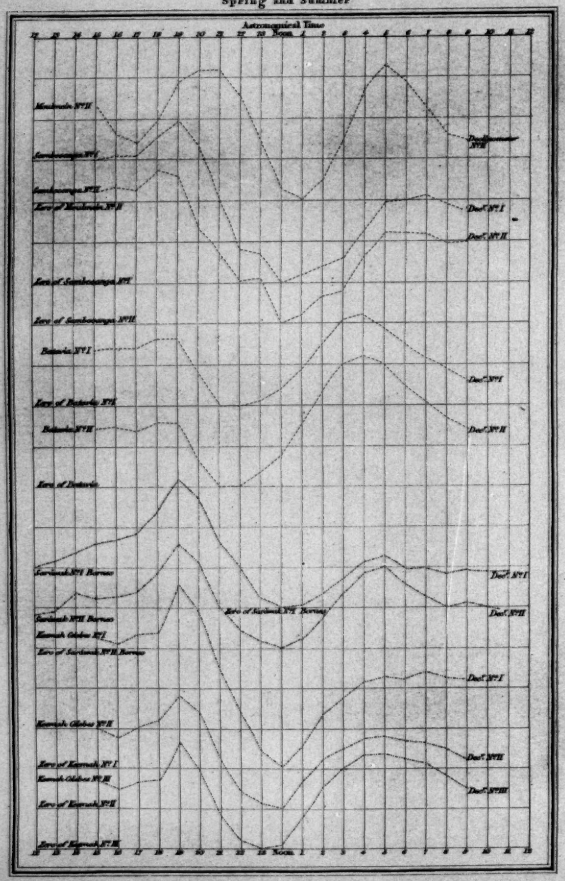
Diurnal Oscillation of the Magnetic Declination at Various Stations in the Eastern Archipelago

PART 2.

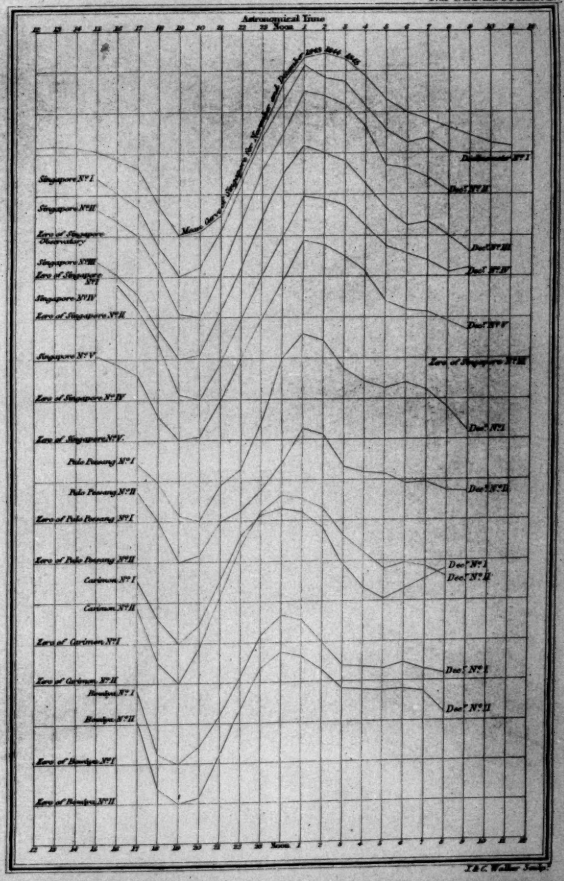
PART 1. PART 2.

Diurnal Oscillation of the Magnetic Declination at Various Stations in the Eastern Archipelago

Spring and Summer



Winter



Scale of 1′ of Arc to 0·35 of an Inch

The Curve Hiring denotes a movement of the North Pole of the Magnet Eastward

Explanation. Winter Spring Summer

PART 1.

Diurnal Oscillation of the Magnetic Declination at Various Stations in the Eastern Archipelago

PART 2.

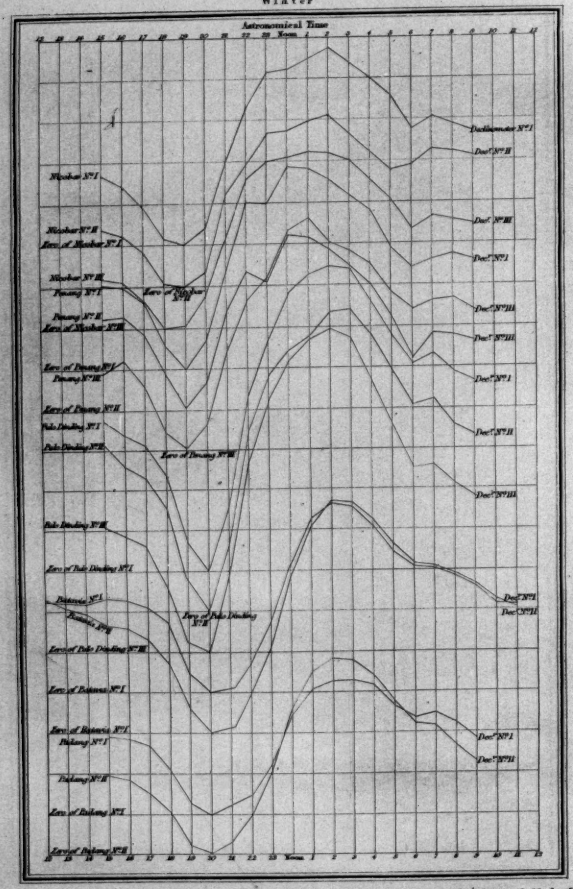
PART I.

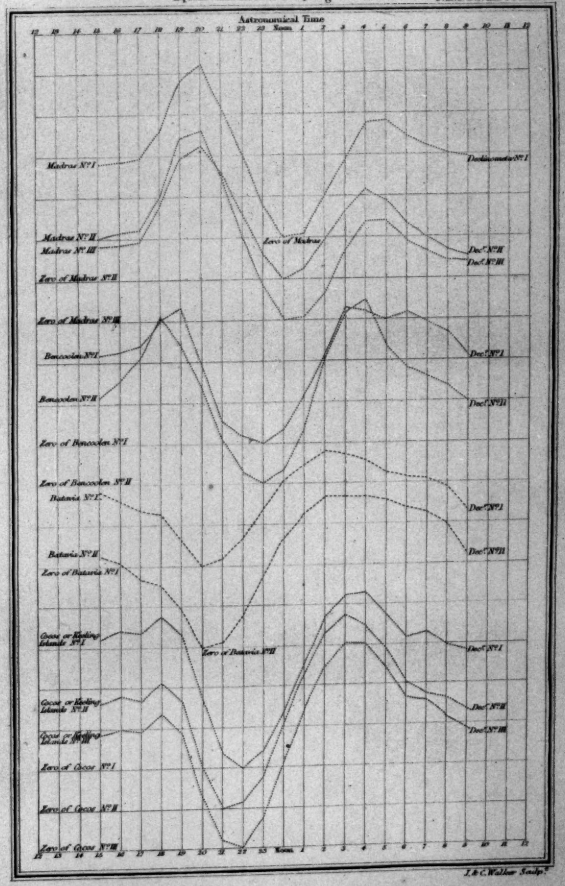
Diurnal Oscillation of the Magnetic Declination at Various Stations in the Eastern Archipelago

Equinoctial Months in Spring & Autumn

Phil. Trans. MDCCCLI. Pl. V.

Winter



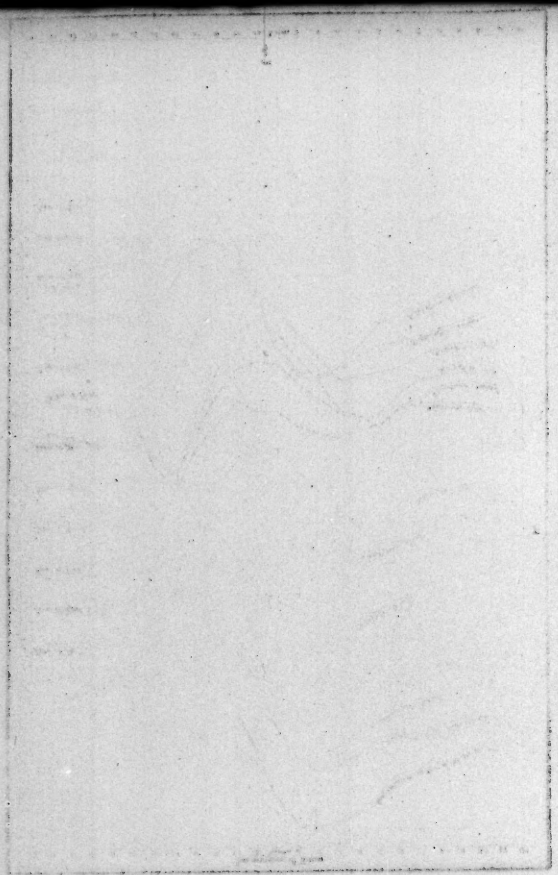


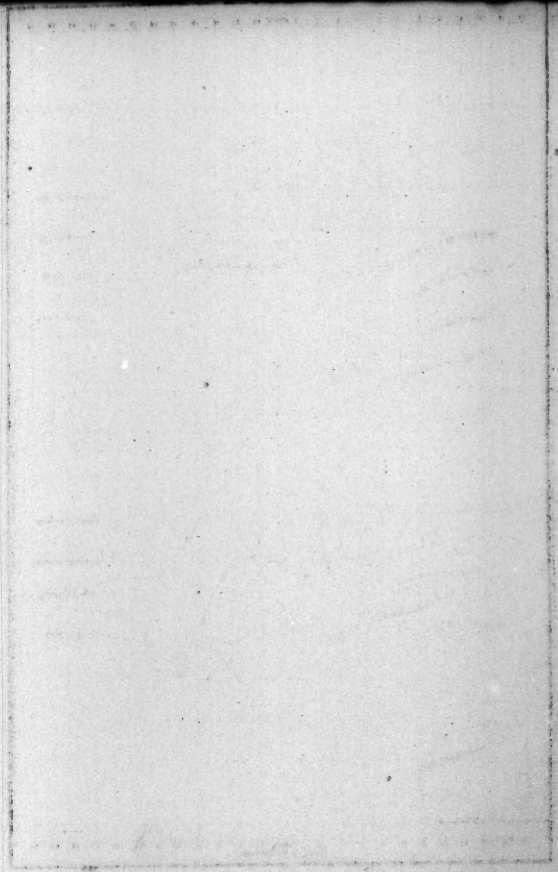
J. & C. Walker Sculp.s

Scale of 1 of Arc to 0·35 of an Inch

The Curve rising denotes a movement of the North Pole of the Magnet Eastward

Explanation Winter Spring Autumn





PART 1

PART 2

Diurnal Oscillation of the Magnetic Declination at Singapore during the Years 1843, 1844, 1845.

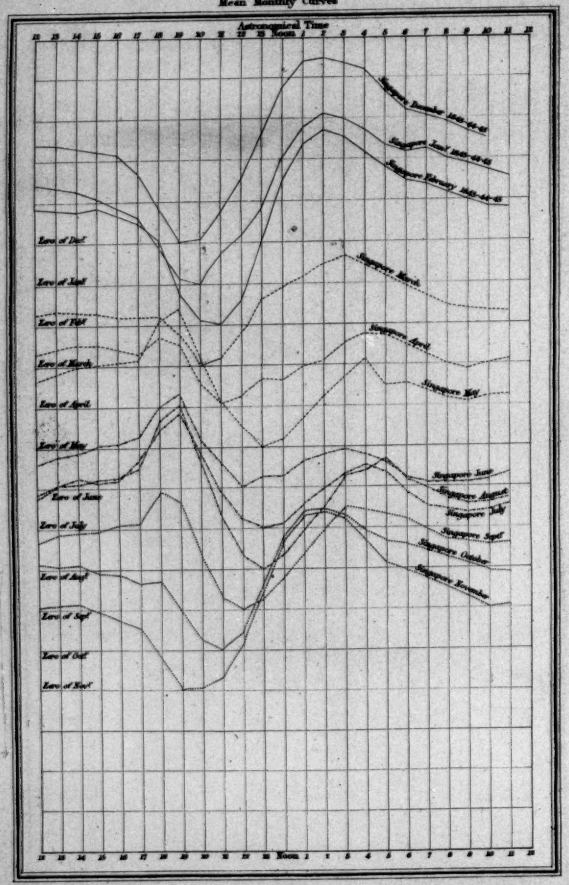
Phil. Trans. MDCCCLI. Pl. VI.

Mean of each of the four Seasons and of each year, and of the General mean.

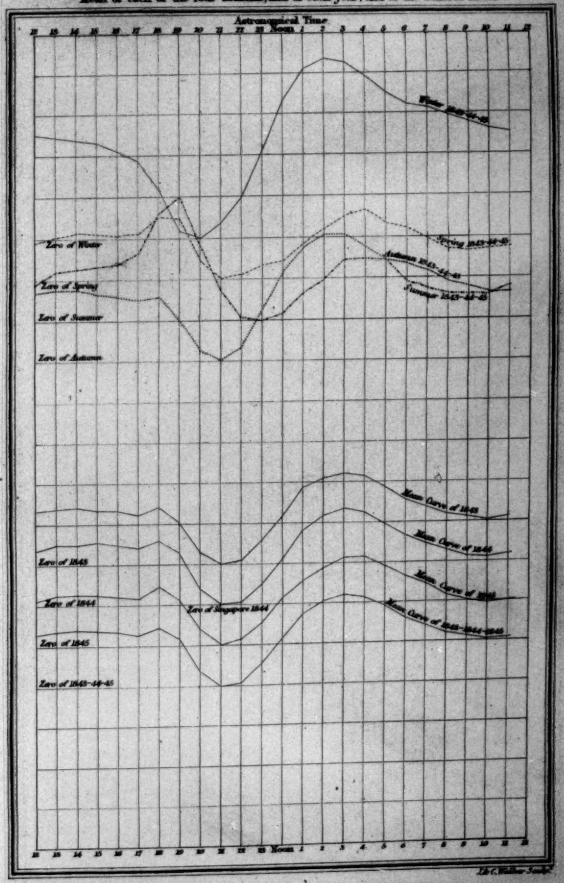
Phil. Trans. MDCCCLI. PL.VI.

Diurnal Oscillation of the Magnetic Declination at Singapore during the Years 1843, 1844, 1845.

Mean Monthly Curves



Mean of each of the four Seasons, and of each year, and of the General mean.



Scale of 0·68 of Arc to 0·35 of an Inch.

The Curve Rising denotes a movement of the North Pole of the Magnet Eastward.

Explanation: Winter ... Spring ... Summer ... Autumn

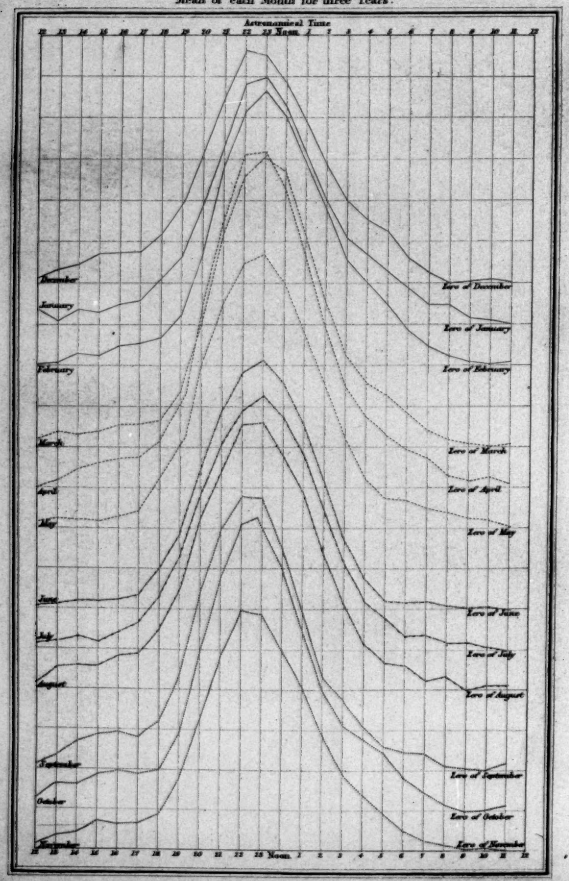
PART 1

PART 2

PART 1

Diurnal Oscillation in Scale Divisions of the Singapore Bifilar Magnetometer.

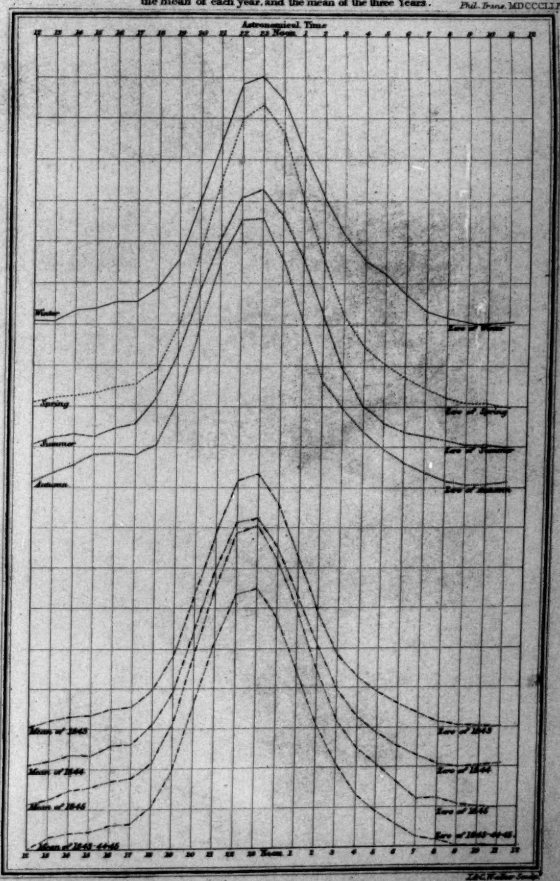
Mean of each Month for three Years.



PART 2

Mean of each of the four Seasons for three Years, the mean of each year, and the mean of the three Years.

Phil. Trans. MDCCCLI. Pl. VII.



One Scale Division .000197 of the Force to 0·35 of an Inch.

The Curve Rising denotes an increase of Horizontal Force

Explanation: Winter, Spring, Summer, Autumn, Yearly Curves

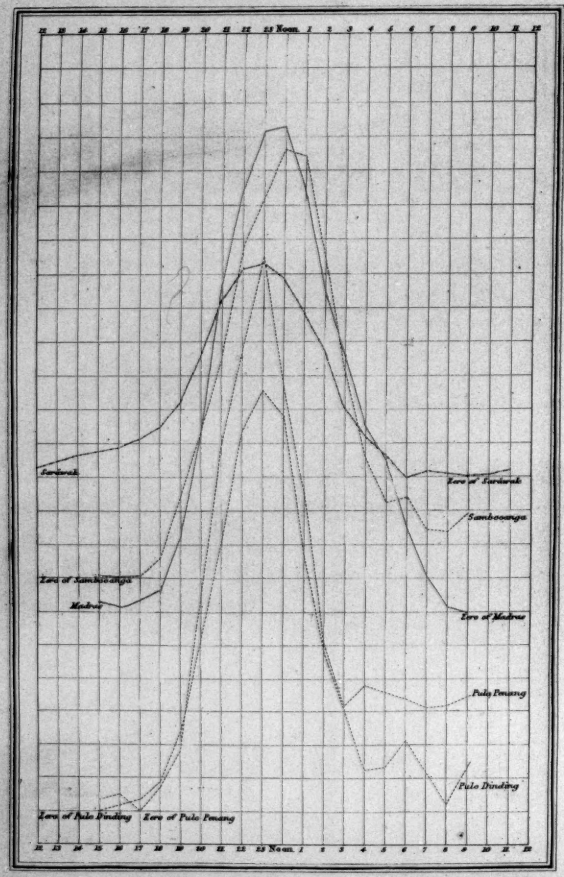
PART 1

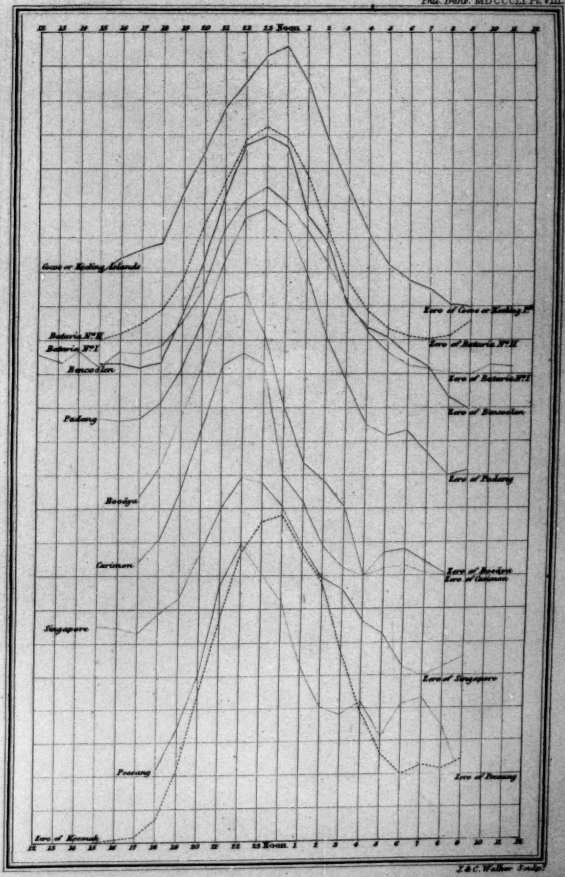
PART 2

Diurnal Oscillation of the Portable Bifilar Magnetometer corrected, in Scale Division at Various Stations in the Eastern Archipelago.

PART 1 PART 2

Diurnal Oscillation of the Portable Bifilar Magnetometer corrected, in Scale Division at Various Stations in the Eastern Archipelago.





J. & C. Walker Sculp.

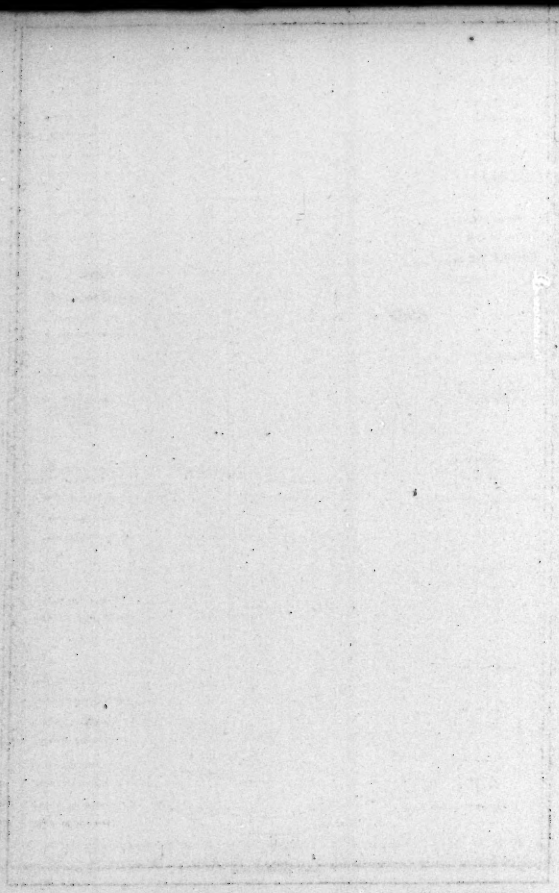
One Scale Division (=0·002402 of the Force) to 0·25 of an Inch.

The Curve Rising denotes an Increase of Force.

Explanation: Winter Spring Summer Autumn

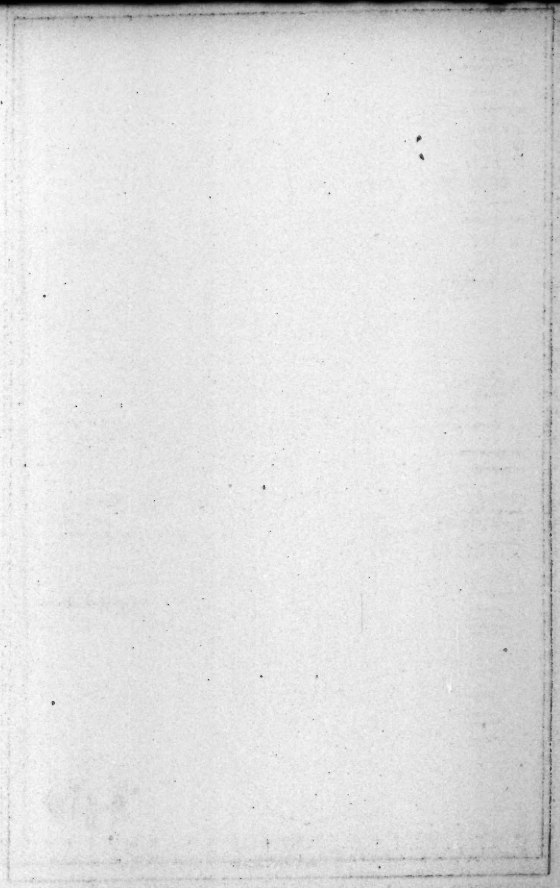
PART 1

Variation of the Wet Bulb Thermometer at various Stations in the Eastern Archipelago.

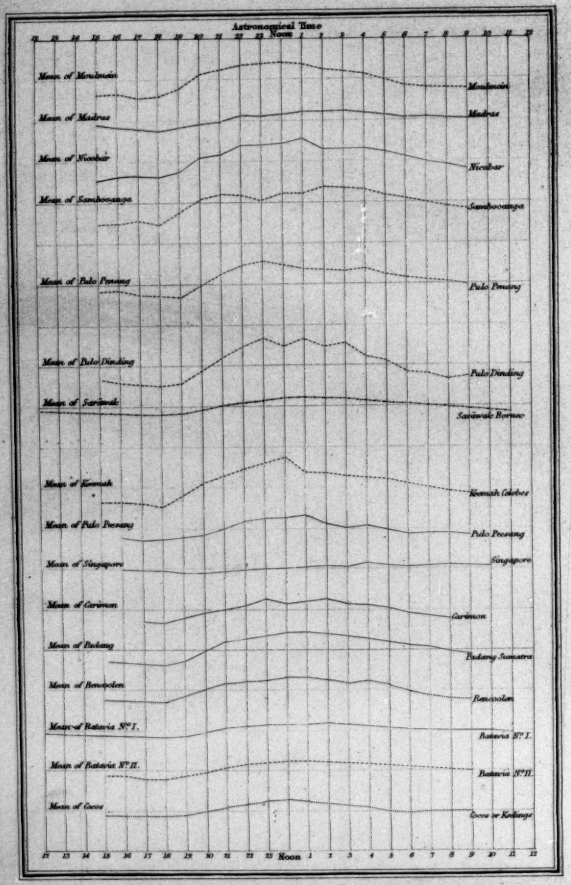


PART 2

Variation of the Standard Thermometer at various Stations in the Eastern Archipelago.



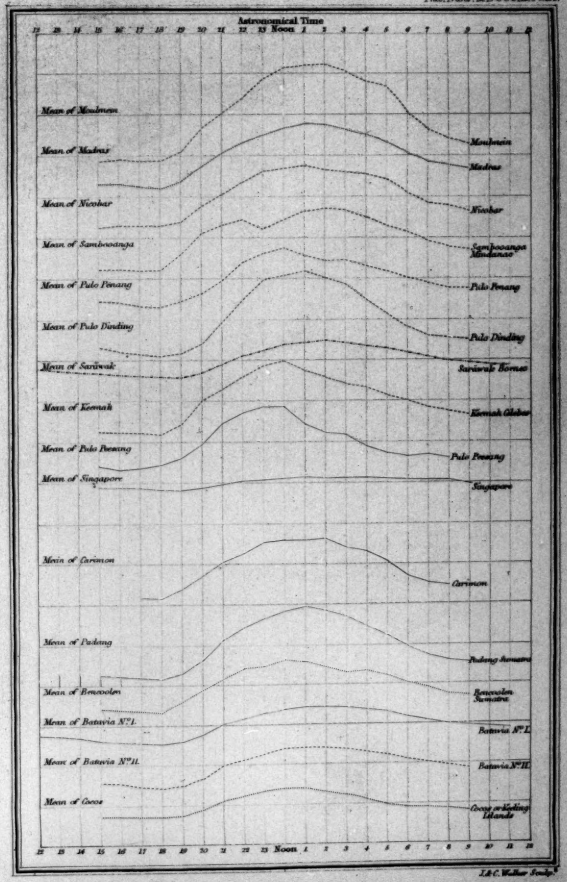
Variation of the Wet Bulb Thermometer at various Stations in the Eastern Archipelago.



Scale of 10° of Wet Bulb to 0·35 of an Inch.
The curve rises with increase of Temperature
Explanation:— Summer — Spring — Autumn ~ Winter

Variation of the Standard Thermometer at various Stations in the Eastern Archipelago.

Phil. Trans. MDCCCLI. Pl. IX.



J. & C. Walker Sculp.

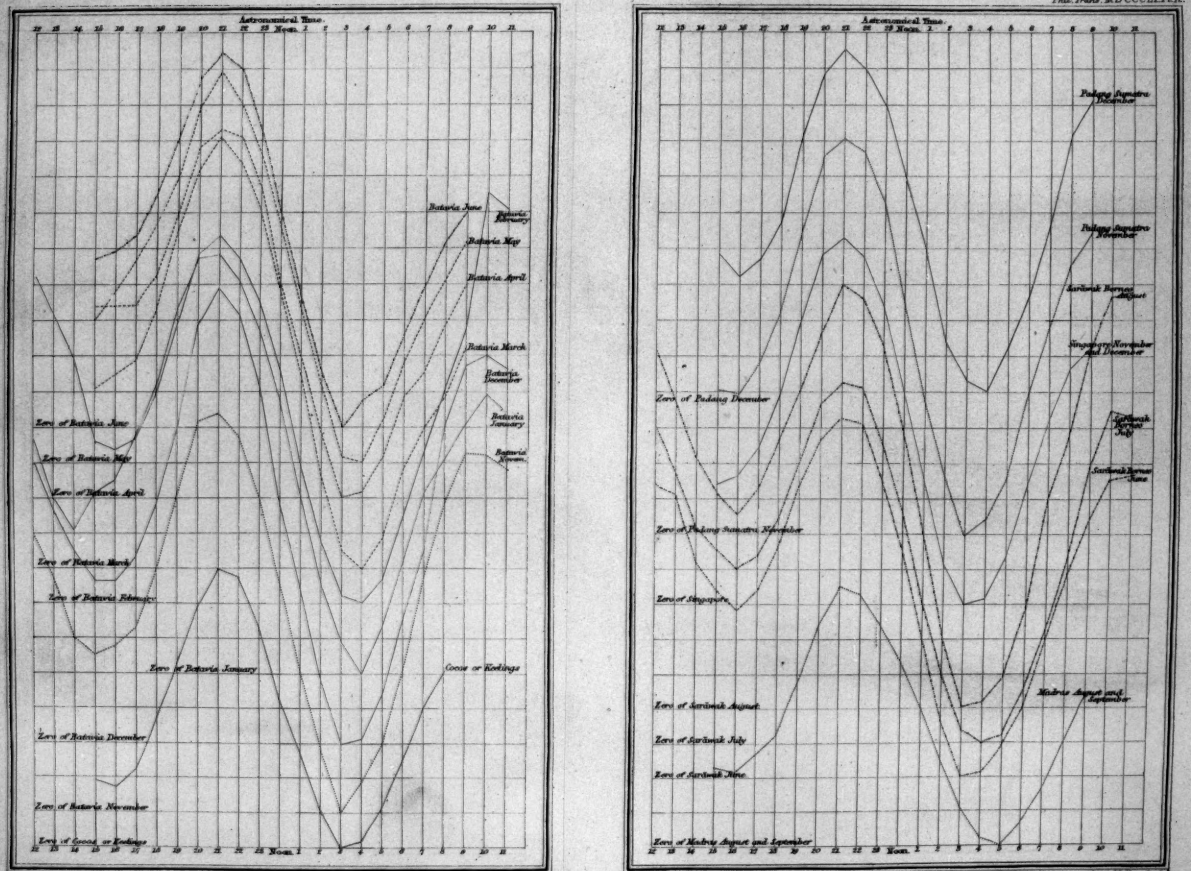
Scale of 10° of Temp.° to 0·35 of an Inch
The curve rises with increase of Temperature
Explanation:— Summer — Spring — Autumn ~ Winter

PART 1

PART 2

Variation of Barometer corrected to 32° at various Stations in the Eastern Archipelago.

Variation of Barometer corrected to 32° at various Stations in the Eastern Archipelago.



Scale of 0·010 of an Inch of Barometric Pressure to 0·30 of an Inch linear measure

Explanation, ——— Summer ——— Spring ——— Autumn ——— Winter

The Curve rising denotes an increase of Pressure

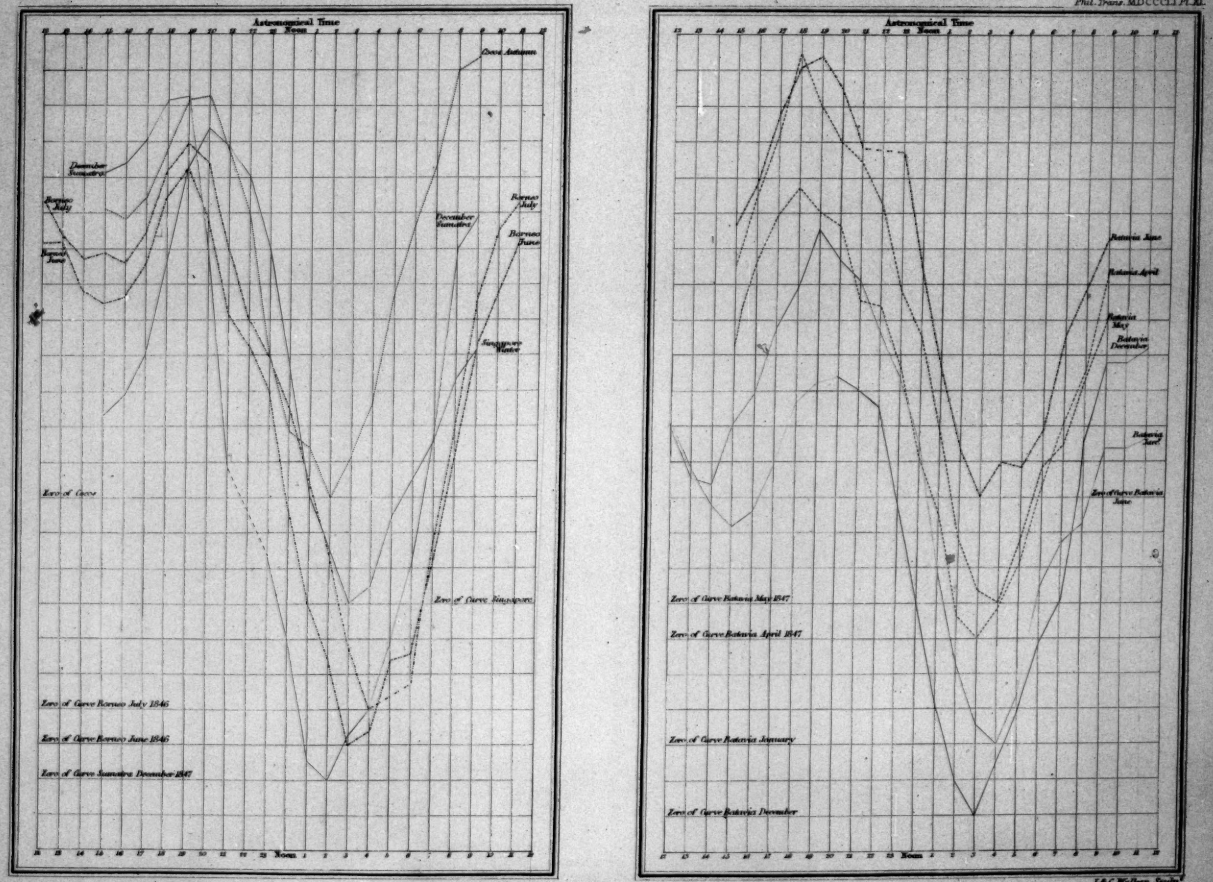
J. & C. Walker Sculp.

PART 1

PART 2

Variation of Gaseous Pressure at different Stations in the Eastern Archipelago

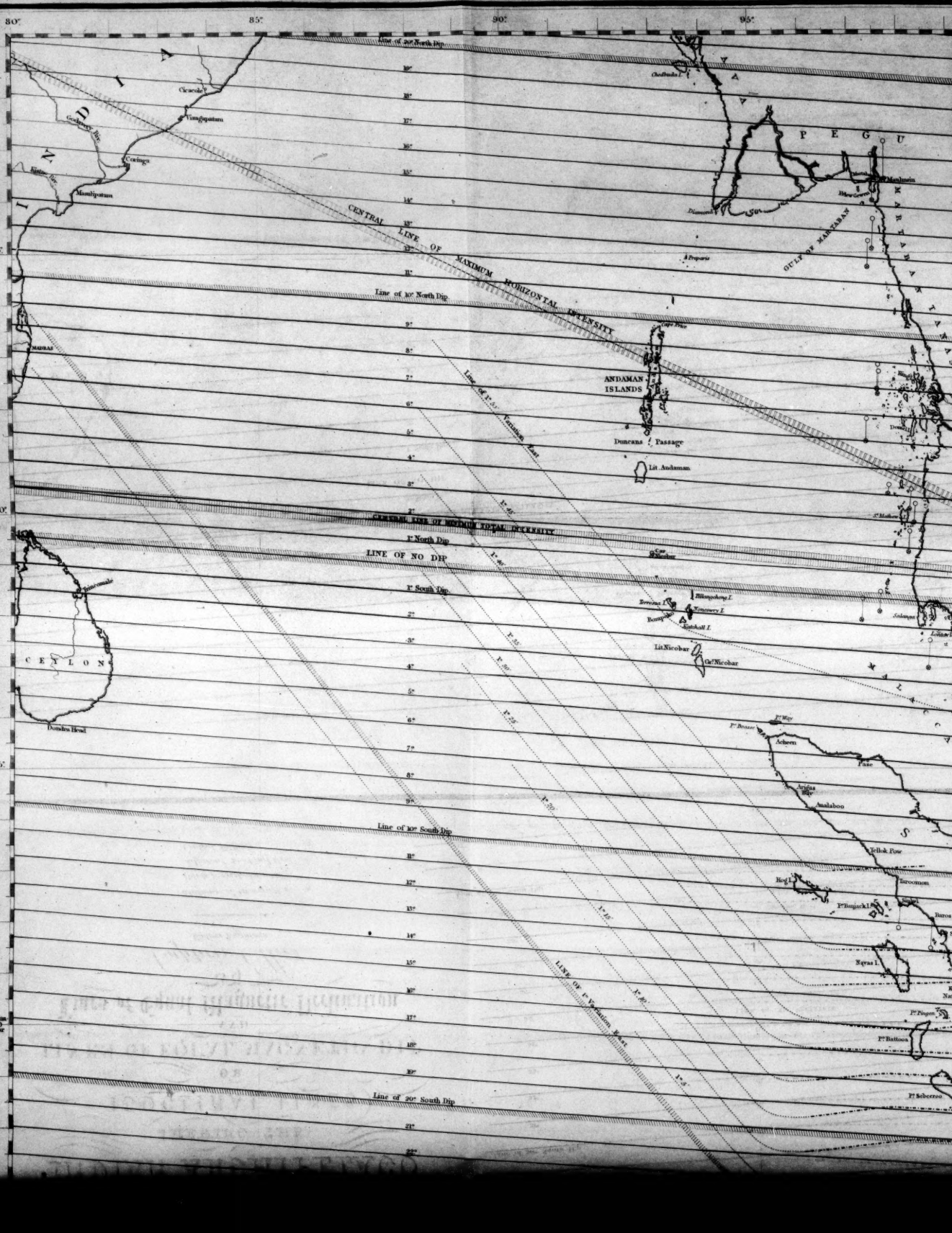
Phil. Trans. MDCCCLI Pl. XI.

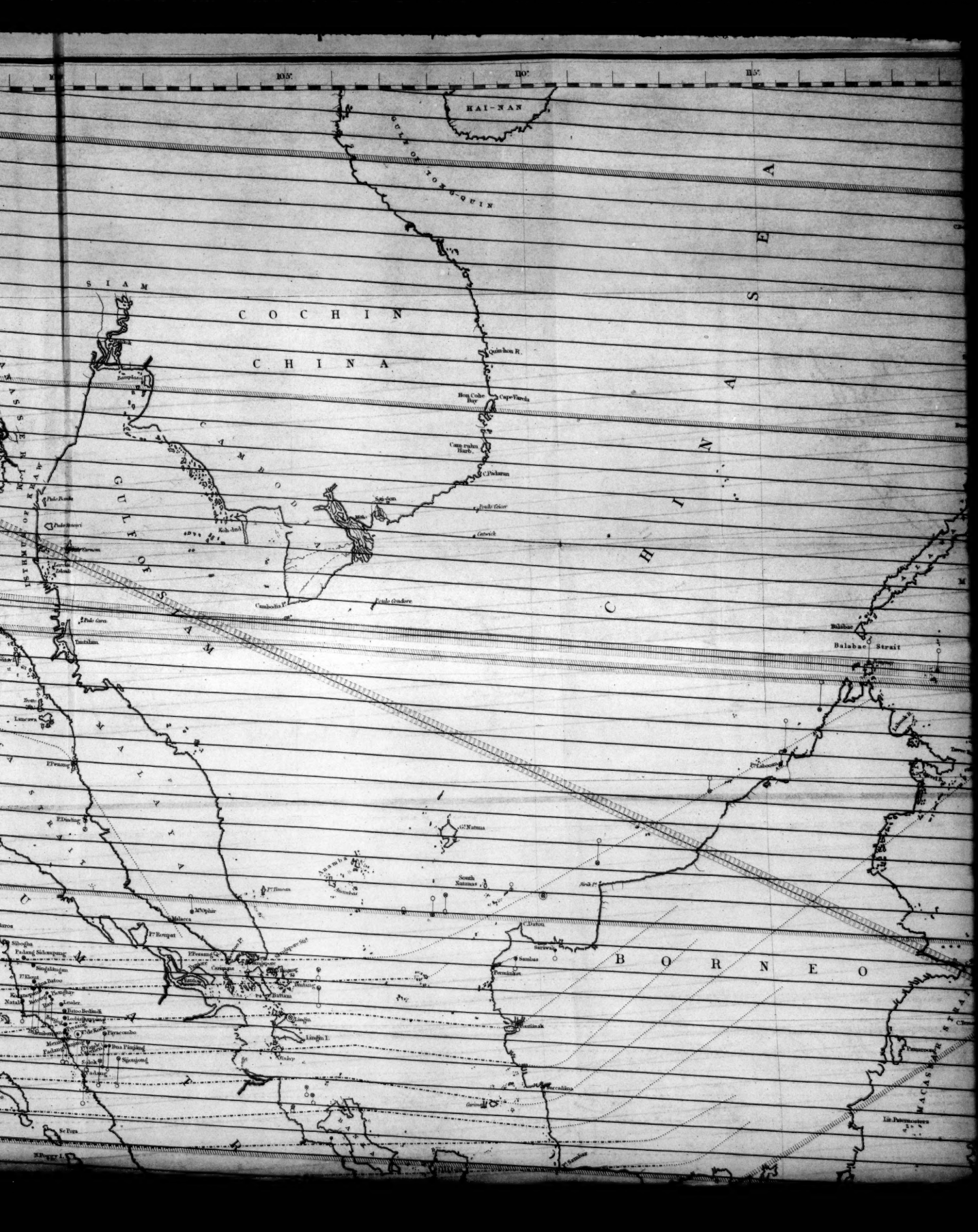


Scale of ·010 of an Inch of Pressure of Mercury to 0·30 of an inch linear measure.

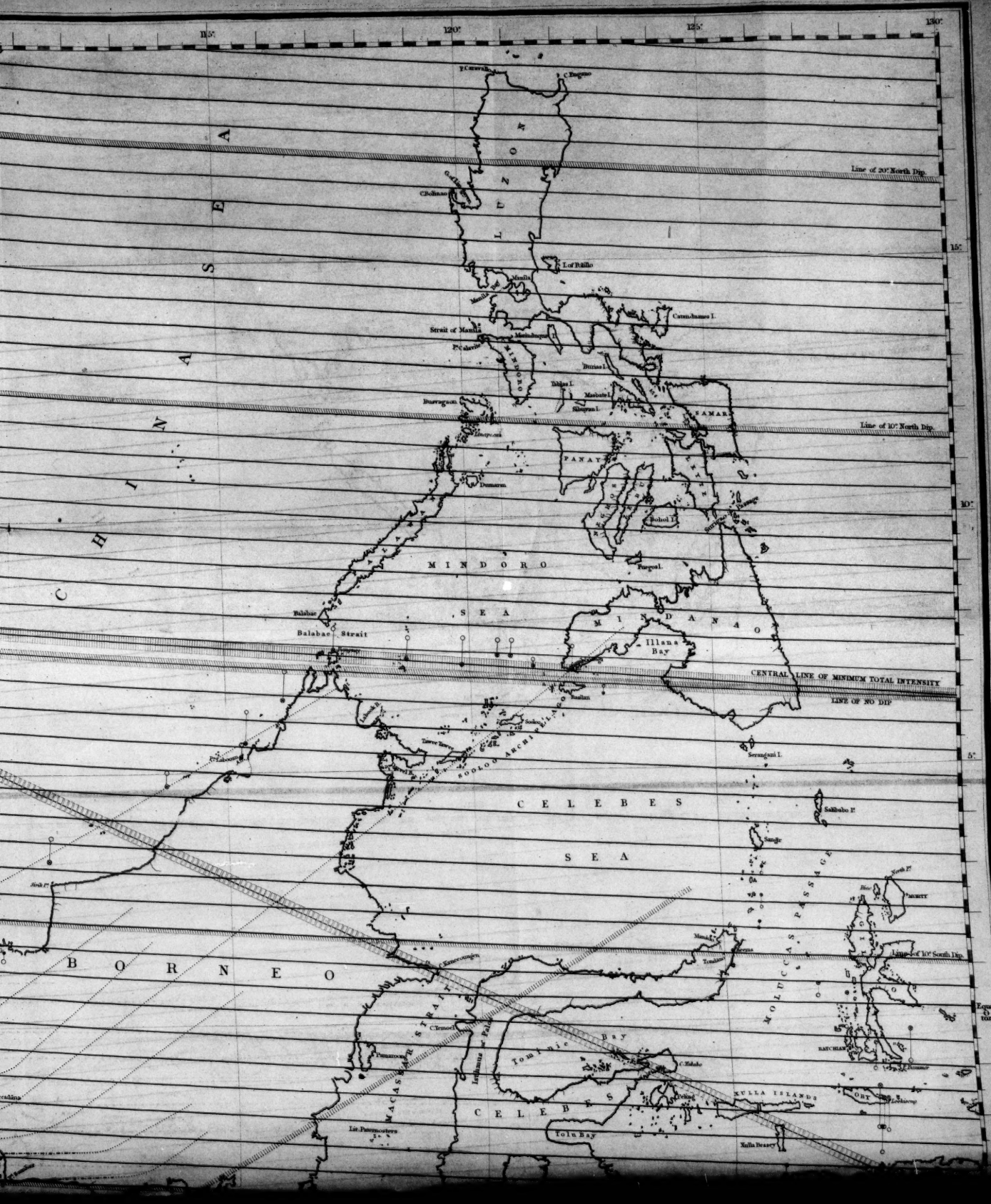
The Curve rises with increase of Pressure.

Explanation: Winter. Spring. Summer. Autumn.


80°
85°
90°
95°
15°
10°
5°
Equator
Line of 30° North Dip
Line of 10° North Dip
Line of 0° Dip
Line of 10° South Dip
Line of 30° South Dip
CENTRAL LINE OF MAXIMUM HORIZONTAL INTENSITY
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
LINE OF NO DIP
Line of 0° Var. Easterly
Line of 0° Var. Westerly
1° North Dip
1° South Dip
INDIA
Cheduba I.
Ramree I.
Cape Negrais
Diamond I.
Rangoon
Martaban
Moulmein
Bluff Cape
GULF OF MARTABAN
PEGU
MARTABAN
Cape Price
ANDAMAN ISLANDS
Duncans Passage
Lit. Andaman
Cape Negrais
Barren I.
Narcondam I.
Bilimpoolong I.
Tremouny I.
Rutland I.
Kotchall I.
Lit. Nicobar
Gr. Nicobar
Sabang
Pt. Way
Pt. Brasse
Acheen
Pase
Arigas R.
Analaboo
Tellok Pow
Barcoman
Pt. Bungack I.
Reg. I.
Sgras I.
Pt. Pagon
Pt. Battoon
Pt. Seberoo
CEYLON
Dondra Head
Point Pedro
MADRAS
Cheduba I.
Cheadubah
Cocanada
Vizagapatam
Godavery Pint.
Coringa
Ristna Cape
Masulipatam


HAI-NAN
GULF OF TONQUIN
SIAM
COCHIN
CHINA
CHINA SEA
Quinhon R.
Bon Cohe Bay
Cape Varela
Camranh Harb.
C. Padaran
Pulo Condore
Cambodia R.
GULF OF SIAM
Pulo Gora
Pulo Panjang
Pulo Timoan
Pulo Aor
Kah Ang
Pulo Condore
Gutwick
Balabac Strait
Balabac
Lancava
Pt. Romat
Pt. Romania
Pt. Romania
Pt. Romania

90°
95°
100
105°
110°
PEGU
GULF OF MARTABAN
MARTABAN
TAVAY
MERGUI ARCHIPELAGO
ANDAMAN ISLANDS
Duncans Passage
Lit. Andaman
Lit. Nicobar
Gt. Nicobar
SIAM
GULF OF SIAM
COCHIN CHINA
CAMBOJA
HAI-NAN
GULF OF TONQUIN
Cape Liant
Cape Varela
Cape Padaran
Pulo Condore
Cambodia R.
Saigon
Quinchon R.
Hon Cohe Bay
Camranh Harb.
C. Padaran
Catwick
Tantalam
Lancawy
Acheen
Pase
Analaboo
Pellok Pow
Broomon
Banca
Linga I.
Lingin I.
Malacca
Singapore
Batam
Bintang
Natuna
South Natunas
Anambas
Sambas
Pontianak
Borneo
Celebes
Java
Sumatra
Timor
HORIZONTAL INTENSITY
INTENSITY
LINE OF NO VARIATION EAST


115°
120°
125°
130°
15°
10°
5°
Equator
Line of 20° North Dip.
Line of 10° North Dip.
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
LINE OF NO DIP
Line of 10° South Dip.
CHINA SEA
SEA
BORNEO
CELEBES
LUZON
MINDORO
PANAY
SAMAR
MINDANAO
Strait of Manilla
Manilla
Balabac Strait
Illana Bay
Tolu Bay
Xulla Islands
Xulla Beasey
Molucas Passage
Macassar Strait
Sooloo Archipelago
Pt Cavite
C Engano
C Bolinao
L of Pililo
Cape Santiago
Pt Calavite
Mindoro Str.
Burias I.
Tablas I.
Masbate I.
Sibuyan I.
Romblon
Bohol I.
Siquijor
Negros
Surigao
Basilan
Serangani I.
Sulibabo I.
Sangir
Miangis
Ternate
Gilolo
Celebes
C Lemoni
Tomini Bay
C Salabo
Peling
Banka
Batchian
Obi
Morty
Amboyna
Laboeng
Tagulandang
Siao
Sanguir
Talaut
Meangis
Sarangani
Cagayan Sulu
Balabac
Palawan
Cuyo
Calamianes I.
Busuanga
Linapacan
Dumaran
Cagayan
Sulu Archipelago

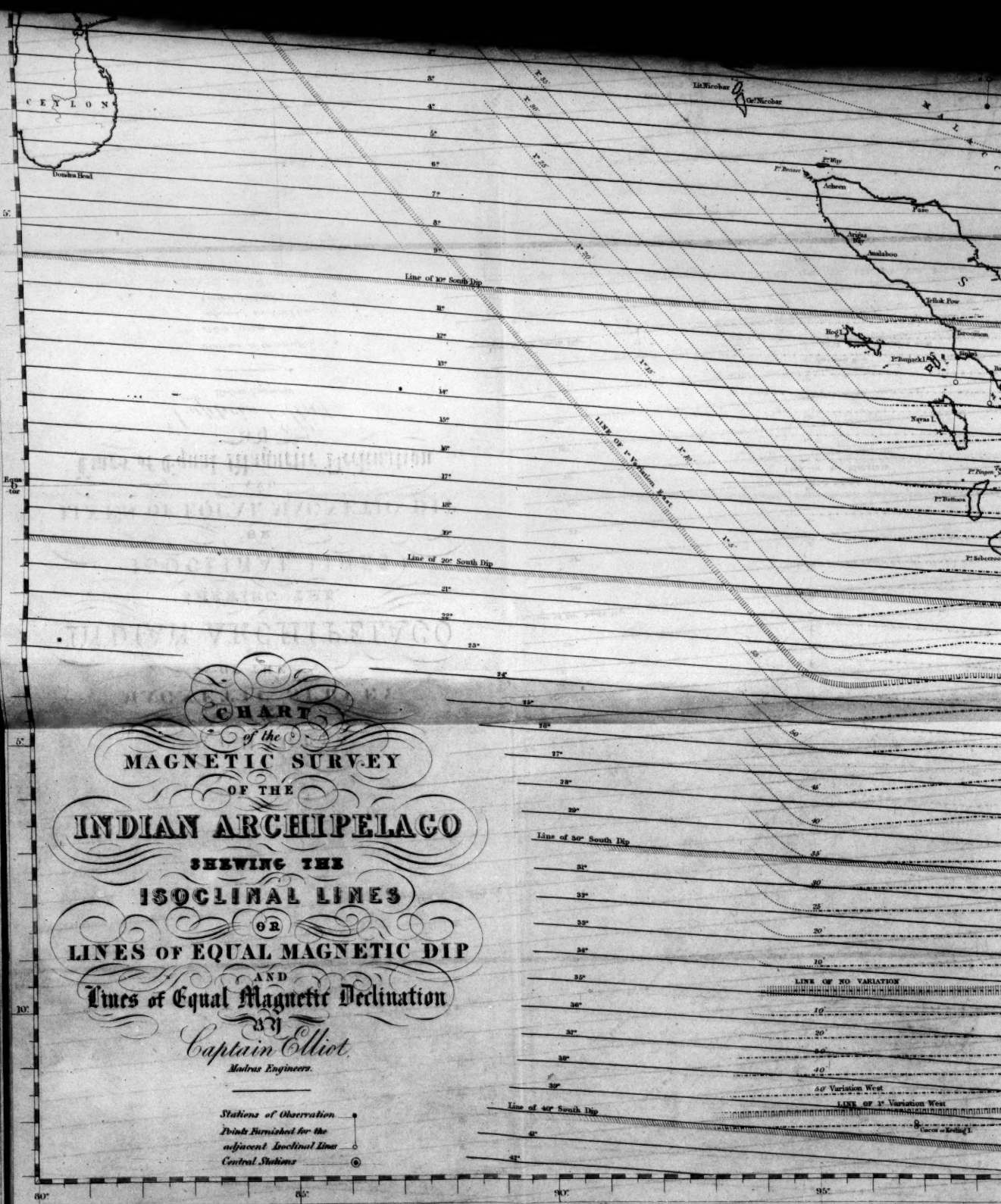
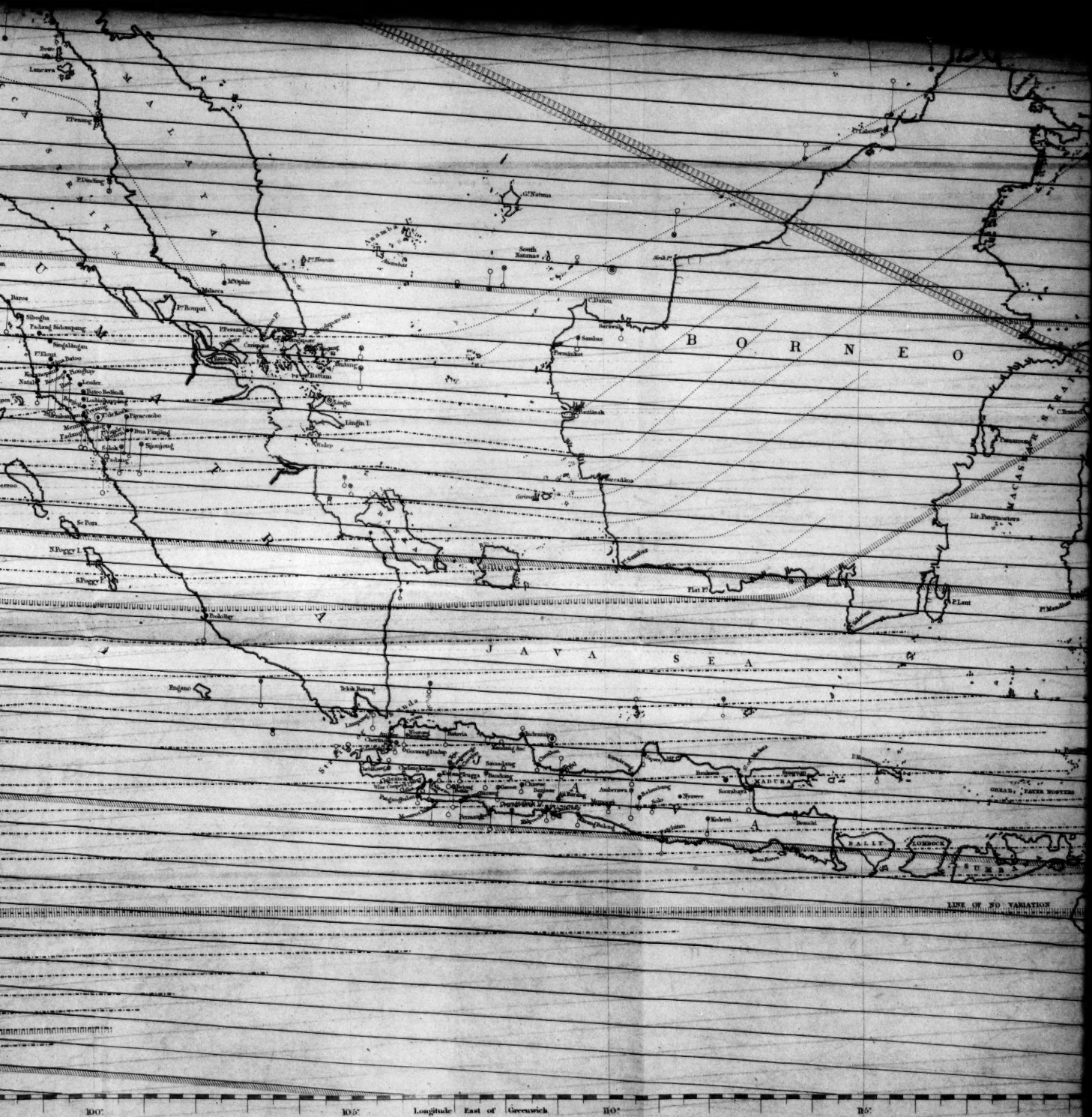
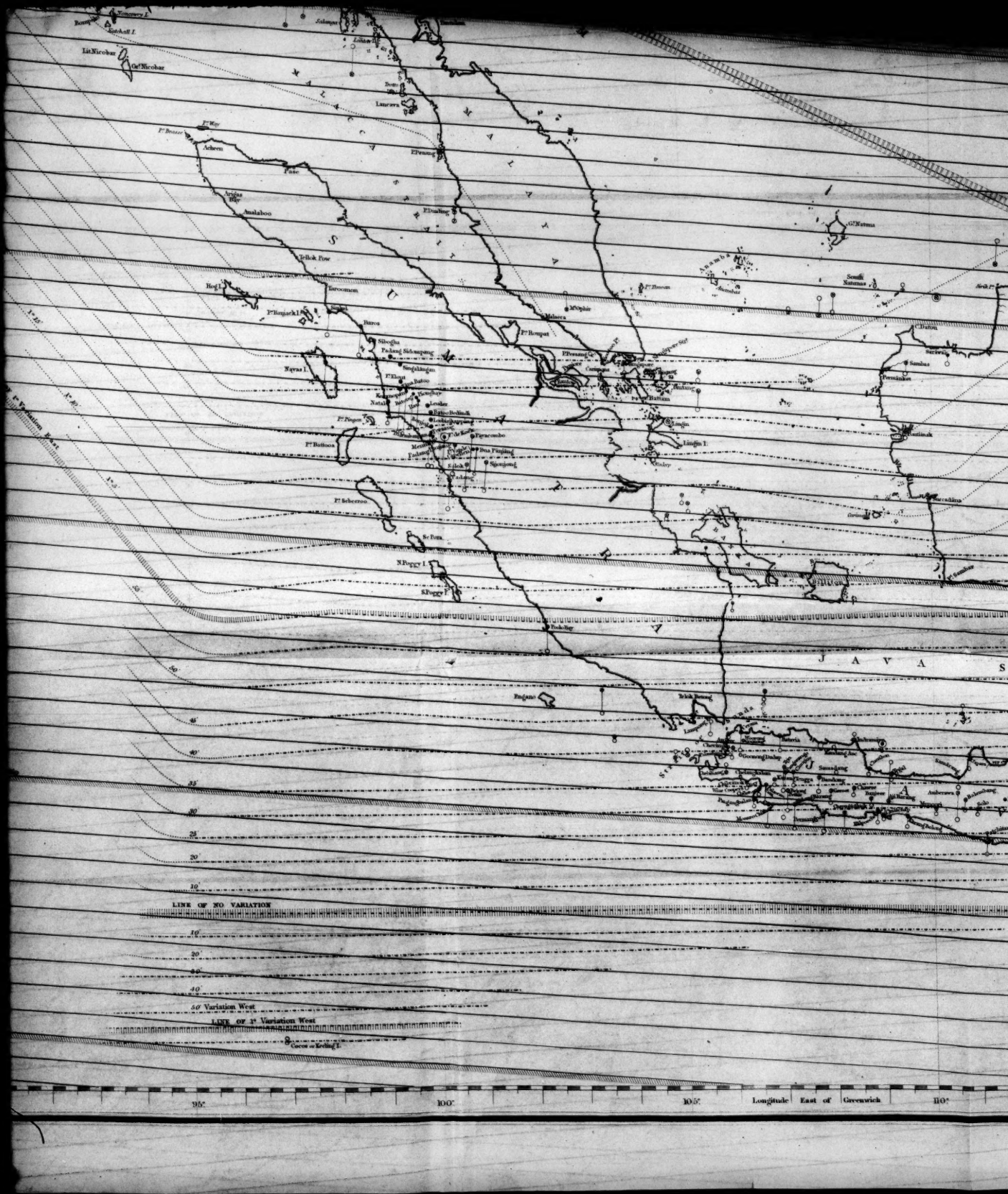


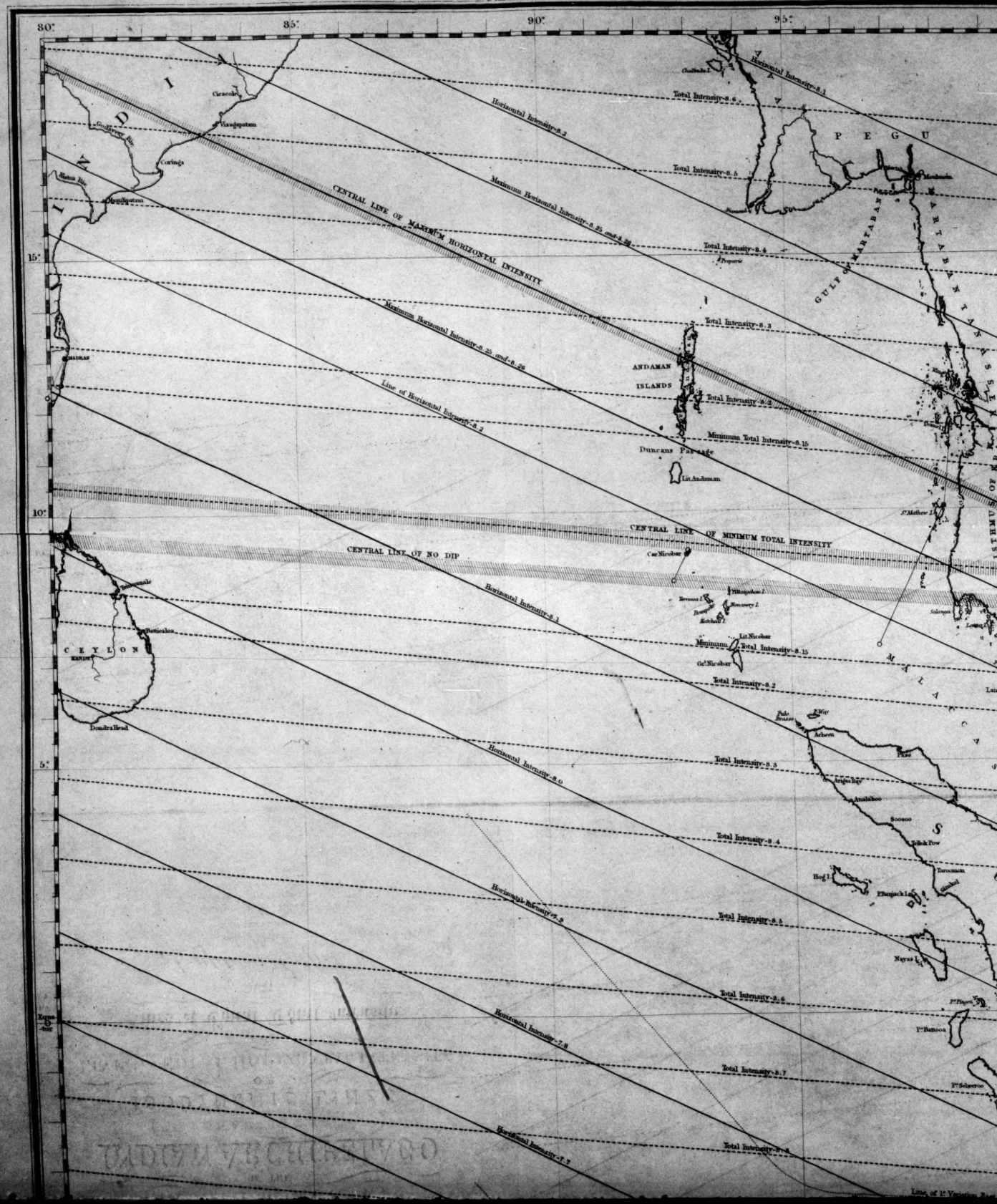
CHART
of the
MAGNETIC SURVEY
OF THE
INDIAN ARCHIPELAGO
SHEWING THE
ISOCLINAL LINES
OR
LINES OF EQUAL MAGNETIC DIP
AND
Lines of Equal Magnetic Declination
BY
Captain Elliot
Madras Engineers.

Stations of Observation
Points Furnished for the adjacent Isoclinal Lines
Central Stations

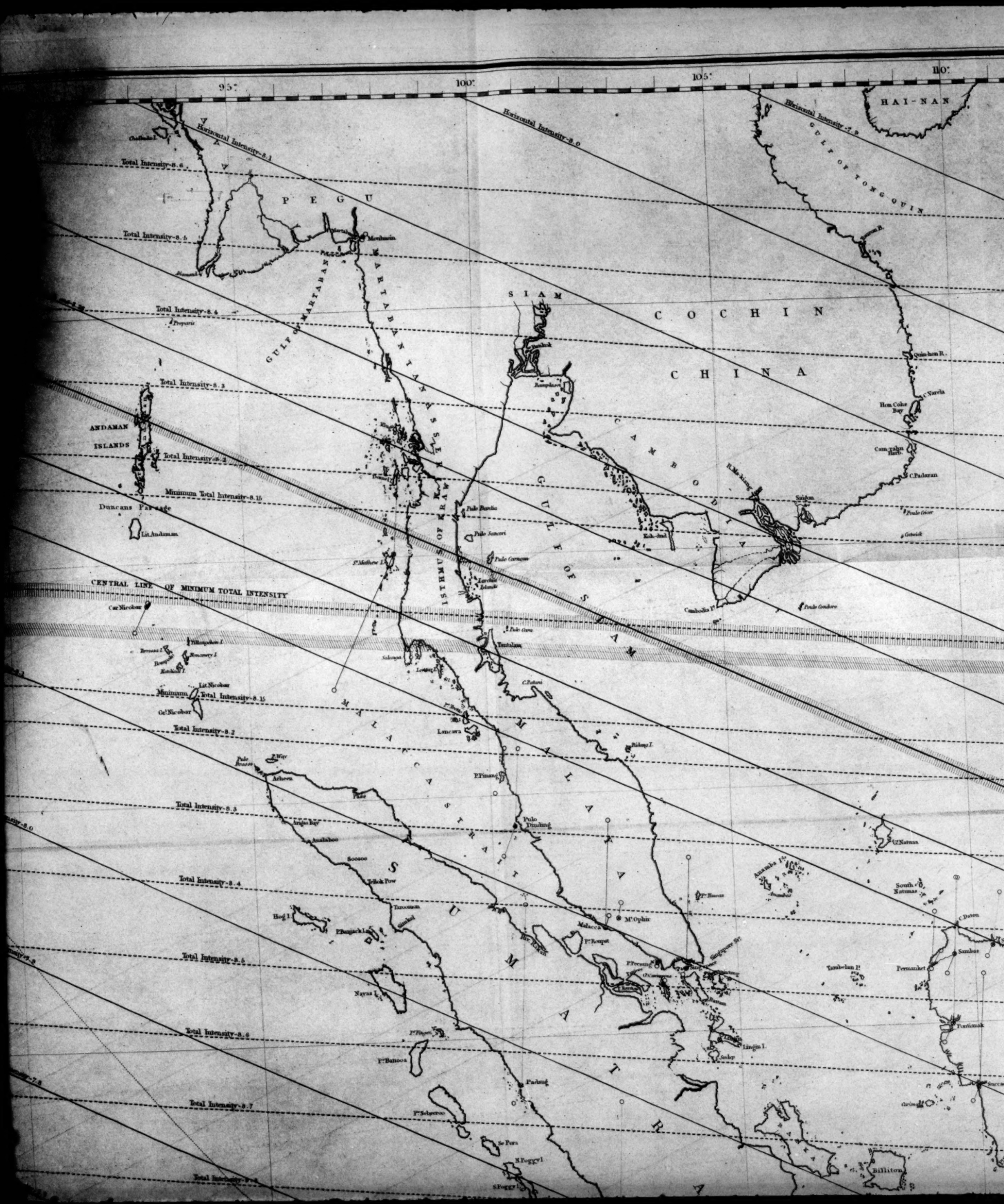

B O R N E O
J A V A S E A
MACASSAR STRAIT
Pt Romput
Linga I.
Lingin I.
Batam
Singapore
Carimon
Natuna
South Natunas
Borneo
Pontianak
Sambas
Datoo
Sillosha
Pulang Sidempang
Singalangan
Lesader
Tapracombo
Bua Pinjang
Sjanjong
Selick
Rhio Bellisli
Lobbo Bedjang
Lobbo Tuah
Mentawi
Pulo Pora
N. Poggy I.
S. Poggy I.
Rodellie
Enggano
Tchek Bentang
Indian Ocean
Sunda Str.
Java Head
Anjer
Batavia
Cheribon
Samarang
Grissee
Sourabaya
Pasuruan
Banjoowangy
Pt Sedano
Amboyna
Bima
Sumbawa
Flat Pt
Pt Leat
Pt Mangalore
Lit Paternosters
Pt Romain
Pt Timoan
Mt Ophir
Malacca
Abreados
Natuna
Pt Penang
Pt Diamond
Pt Penang
Pt Elliot
Pt Rhio
Bantam
Cheribon
Gt Natuna
Barrow
Tandjong Sambar
Tandjong Datoo
Tandjong Sirik
Tandjong Kandangan


Bengal
Montgomery I.
Katchall I.
Lit. Nicobar
Gt. Nicobar
Sabanger
Lancava
Pt. Way
Pt. Brazier
Achem
Pase
Arrakan Hill
Analaboo
Pt. Penang
P. Dinding
Tellok Pose
Rog I.
Barcoomen
Pt. Romjack I.
Baroa
Siboglia
Padang Sidsanpang
Singkalangan
Ngras I.
P. Elliot
Batoo
Natal
Pt. Pongon
Pt. Battoos
Pt. Seberoo
Sc. Pora
N. Poggy I.
S. Poggy I.
Pt. Rompat
P. Pinang
Malacca
Pt. Trevan
M'Cluer
Arrambo
Sambat
Gt. Natuna
South Natunas
Batam
Lingin
Lingin I.
Cloley
Paracombo
Pulo Pinjang
Sijanjong
Selick
Padang
Pedoe Bay
England
Trick Bunny
Samalas
Persaukan
Gurimbo
Sumatra
JAVA
Cheribon
Gt. Samarang
Samarang
Pt. Cocos or Keeling I.
LINE OF NO VARIATION
10'
20'
30'
40'
50' Variation West
LINE OF 1° Variation West
95°
100°
105°
Longitude East of Greenwich
110°

Engraved by J. & C. Walker


80°
85°
90°
95°
15°
10°
5°
INDIA
Ceylon
Dondra Head
Pointe de Galle
Trincomale
Paumben
Ramnad
Negapatam
Tranquebar
Coringa
Masulipatam
Ghareem Pt.
Ratna Pt.
Goa
Carwar
Mangalore
Cranganore
Cochin
Anjengo
Tellicherry
Calicut
Pegu
Martaban
Gulf of Martaban
Moulmein
Prepare
Negrais
Ramree I.
Cheduba I.
Andaman Islands
Duncans Passage
Lit. Andaman
Car Nicobar
Lit. Nicobar
Great Nicobar
Pulo Brasse
Achem
Pedir
Arigas bay
Analaboo
Sooroo
Pulo Pow
Barcoosan
Hogl I.
Panjacka I.
Nayas I.
P. Plaque
P. Batoon
P. Schierron
Sabang
Malacca
Sumatra
Horizontal Intensity-8.1
Total Intensity-8.6
Horizontal Intensity-8.2
Total Intensity-8.5
Maximum Horizontal Intensity-8.32 and 8.28
CENTRAL LINE OF MAXIMUM HORIZONTAL INTENSITY
Total Intensity-8.4
Total Intensity-8.3
Maximum Horizontal Intensity-8.32 and 8.28
Line of Horizontal Intensity-8.3
Total Intensity-8.2
Minimum Total Intensity-8.15
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
CENTRAL LINE OF NO DIP
Horizontal Intensity-8.1
Minimum Total Intensity-8.15
Total Intensity-8.2
Horizontal Intensity-8.0
Total Intensity-8.3
Total Intensity-8.4
Horizontal Intensity-7.9
Total Intensity-8.5
Total Intensity-8.6
Horizontal Intensity-7.8
Total Intensity-8.7
Horizontal Intensity-7.7
Total Intensity-8.8

100°
105°
110°
115°
Horizontal Intensity-8.0
Horizontal Intensity-7.9
Horizontal Intensity-7.8
Horizontal Intensity-7.7
HAI-NAN
GULF OF TONQUIN
SIAM
COCHIN
CHINA
CHINA SEA
CAMBODIA
GULF OF SIAM
Quinhon R.
C. Varella
Hon Cobe Bay
Camranh Bay
C. Padaran
R. Me Kaung
Saigon
Poulo Obie
Poulo Gambir
Poulo Condore
Poulo Panjang
Poulo Sancori
Poulo Cormon
Kah-tual
Camboja R.
Tantalam
Balabac Strait
Lancava
Pinang I.
Poulo Dinding
Malacca
Mt. Ophir
Pt. Rompot
Pt. Tenkin
Singapore
Linga I.
Singkep
Pedang
Billiton
Natuna I.
South Natuna
Tambelan Is.
Pemankat
Sambas
Sarawak
C. Datoo
Pontianak
Borneo
Flat Pt.
Line of Pt. Victoria Reef
MALACCA
STRAITS OF
SUMATRA


95°
100°
105°
110°
Horizontal Intensity-8.1
Horizontal Intensity-8.0
Horizontal Intensity-7.8
Total Intensity-8.6
Total Intensity-8.5
Total Intensity-8.4
Total Intensity-8.3
Total Intensity-8.2
Minimum Total Intensity-8.15
Total Intensity-8.2
Total Intensity-8.3
Total Intensity-8.4
Total Intensity-8.5
Total Intensity-8.6
Total Intensity-8.7
Total Intensity-8.8
PEGU
SIAM
COCHIN CHINA
CAMBODIA
HAI-NAN
GULF OF TONG-QUIN
GULF OF MARTABAN
ISTHMUS OF KRAW
ANDAMAN ISLANDS
Duncans Passage
Lit. Andaman
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
Car Nicobar
Lit. Nicobar
Gt. Nicobar
MALACCA STRAITS
SUMATRA
Malacca
Pt. Rouget
Singapore
Lingin I.
Billiton
Banka
Pulo Dinding
Pulo Pinang
Pulo Bras
Acheen Head
Pulo Jore
Pulo Panjang
Pulo Aor
Pulo Condore
Cambodia Pt.
Saigon
Hon Cohe Bay
C. Varela
C. Padaran
Cam-rahn Bay
Quin-hon R.
Pulo Timoan
Pulo Tingie
Pulo Aroa
Pulo Sancori
Pulo Carnegan
Pulo Gara
Tambelan
Lancawa
Nayas I.
Pt. Batuoa
Pt. Scheroer
Pt. Rogers
Pt. Pessang
Pt. Romania
Pt. Roberts
Pt. Bencoolen
Pt. Manoa
Pt. Tamban
Pt. Sambas
Pt. Datoe
Pt. Simpang
Pt. Tanjong
Pt. Tanjong Kalong
Pt. Tanjong Datoe
Pt. Tanjong Kalong
Pt. Tanjong Datoe
Pt. Tanjong Kalong
Pt. Tanjong Datoe

115°
120°
125°
130°
15°
10°
5°
Horizontal Intensity -7.8
Horizontal Intensity -7.7
Horizontal Intensity -7.6
C. Engano
C. Bolinao
Manila
Strait of Manilla
C. Calavite
Catanduanes
Marinduque I.
Tablas I.
Masbate I.
Sibuyan I.
Burias Island
Dumaran
Panay
Samar
Leyte
Bohol I.
Forgue I.
MINDORO
SEA
MINDANAO
Balabac
Balabac Strait
Illana Bay
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
CENTRAL LINE OF NO DIP
Basilan
Serangani I.
Sulu Archipelago
Tawee Tawee
Sibutu
Sibuco B.
Labuck B.
Sandakan
Sulu Sea
CELEBES
Salibabu I.
Sangir
Miangas
Talaut Is.
MORTY
Mangindano
Sarawak
BORNEO
Cape Datu
Ay. C. Unsel
Pamarongan
Isthmus of Palos
Tomini Bay
G. Tolole
BATCHIAN
OBY
Sucadana
Tolu Bay
Boo Is.
Flat P.t
Line of 1° Variation East
MOLUCCAS PASSAGE

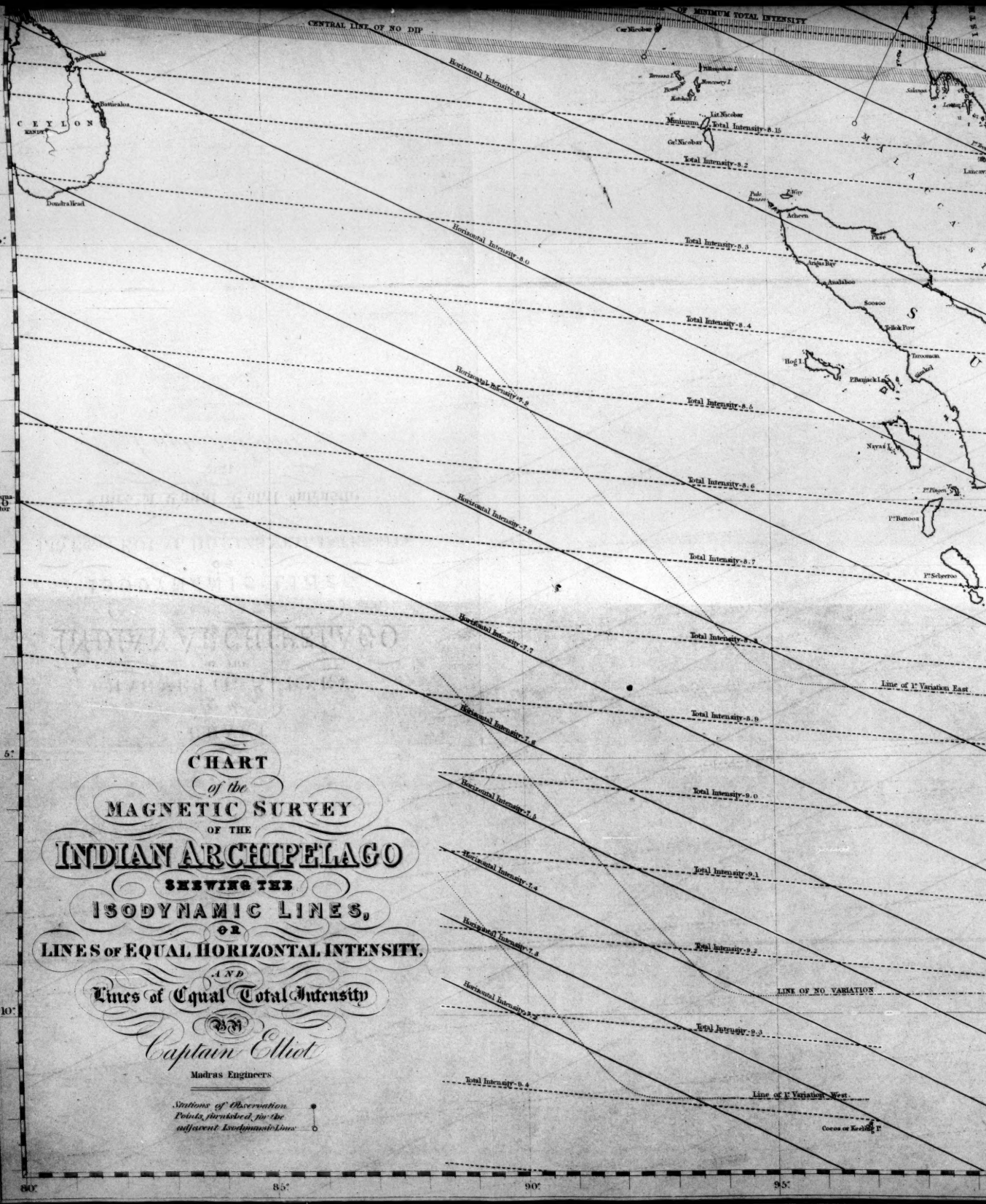
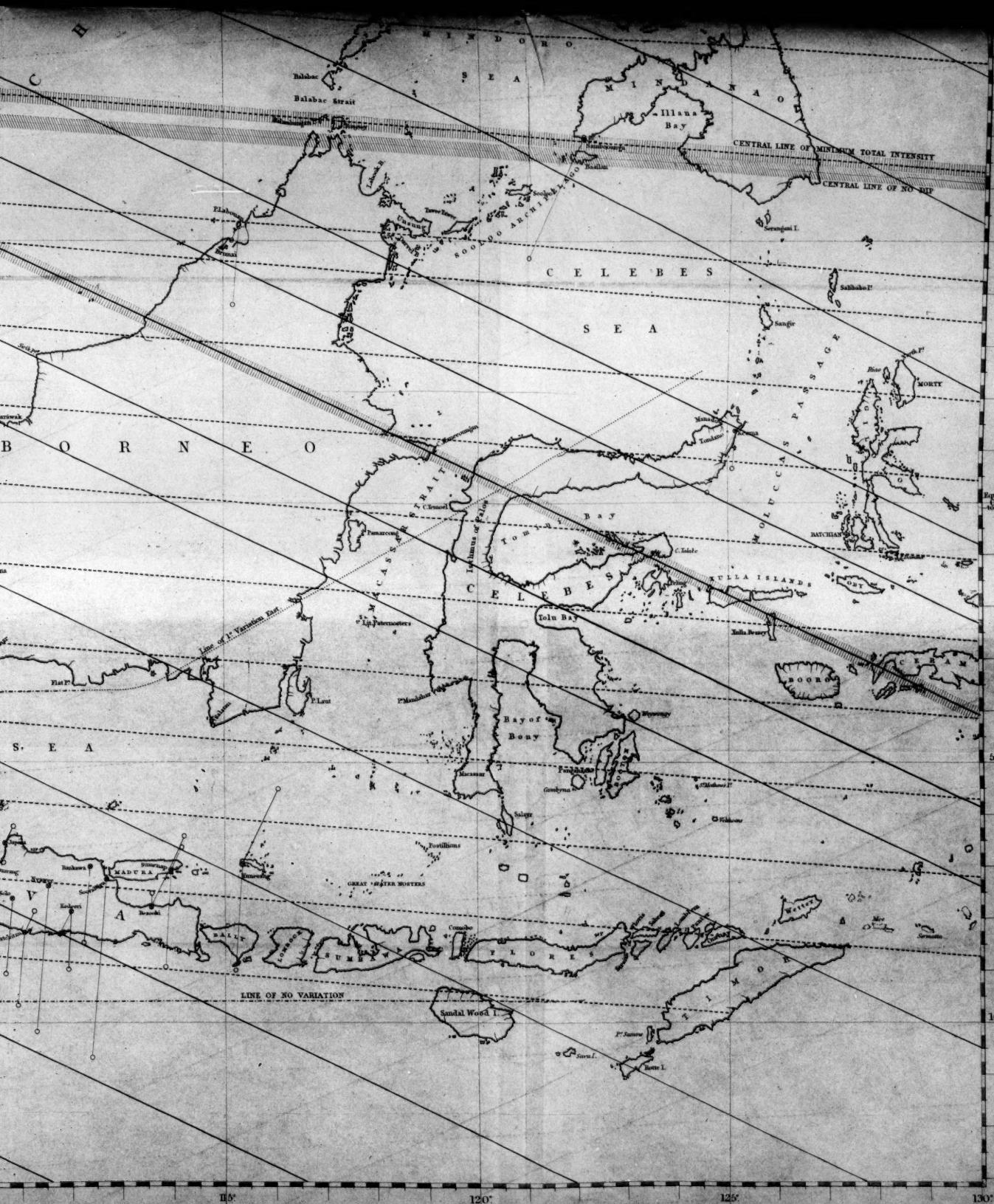


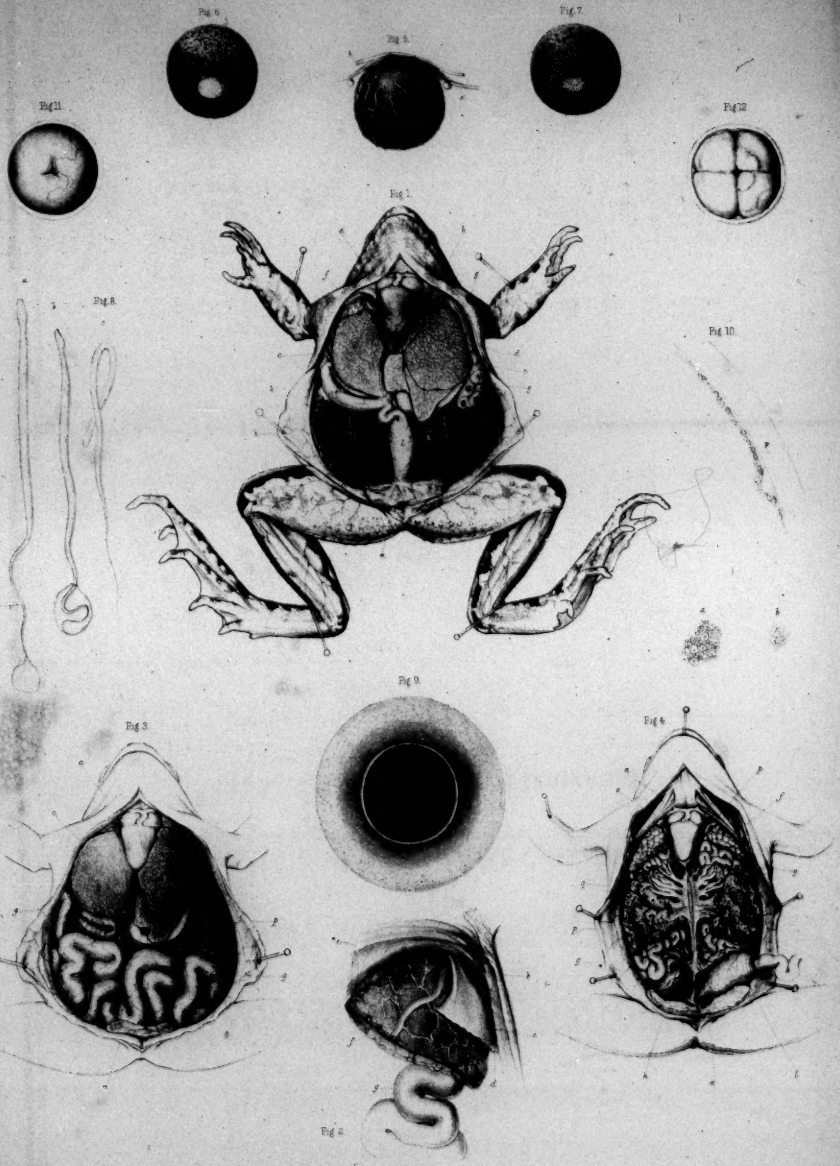
CHART
of the
MAGNETIC SURVEY
OF THE
INDIAN ARCHIPELAGO
SHEWING THE
ISODYNAMIC LINES,
OR
LINES OF EQUAL HORIZONTAL INTENSITY,
AND
Lines of Equal Total Intensity
BY
Captain Elliot
Madras Engineers

Stations of Observation. Points furnished for the different Isodynamic Lines

Cambodia P.
Poulo Condore
Balabac
Balabac Strait
Pulo Aor
Pulo Timoan
C. Patani
P. Pinang
Ridge I.
Palo Dinding
C. Natuna
South Natunas
Anambas
Pt. Rocon
Malacca
M.Ophir
Pt. Roqut
Sangapore Str.
P. Pesang
Tambelan I.
Permanket
Sambas
Sarawak
B O R N E O
Pontianak
Linguin I.
Lingen
Parlang
Succadana
Pasarcoon
Cape Tanjong Sambar
Billiton
Line of 1° Variation East
Pt. Lani
Pt. Poco Bay
J A V A S. E A
Enggano
Telok Betung
Cheribon
Batavia
Samarang
Japara
Sourabaya
MADURA
Buckawa
Banca
Sabi
Kedgeri
Banoki
Pasuruan
Postilions
GREAT WATER MOSTERS
BALLY
LOMBOCK
SUMBAWA
LINE OF NO VARIATION
100°
Longitude East of Greenwich.
105°
110°
115°

OF MINIMUM TOTAL INTENSITY
Car Nicobar
Terressa I.
Bompoka I.
Katchall I.
Trinkenbar I.
Nancowery I.
Lat. Nicobar
Minimum Total Intensity 8.15
Gt. Nicobar
Total Intensity 8.2
Total Intensity 8.3
Total Intensity 8.4
Total Intensity 8.5
Total Intensity 8.6
Total Intensity 8.7
Total Intensity 8.8
Total Intensity 8.9
Total Intensity 9.0
Total Intensity 9.1
Total Intensity 9.2
Total Intensity 9.3
Line of 1° Variation East
Line of 1° Variation West
LINE OF NO VARIATION
Cocos or Keeling I.
Pulo Nias
Pulo Batee
Sukanee
Lenangi I.
Pulo Gorn
Pulo Jamma
Camorcotta P.
Pedir
Arroe Gondore
C. Rutessi
Lancawa
Pulo Wey
Acheen
Pulo Breuen
Ridang I.
P. Pinang
Pulo Dinding
Analaboo
Soosoo
Telok Pow
Hog I.
Pt. Jackal
Pt. Rutan
Malacca
M'Cyphir
Pt. Bonpot
Sincapore St.
Singapore
Tambelan Is.
Natunas
South Natunas
Anambas Is.
Bunguran
Pt. Bowan
Pt. Datoon
Sarawak
Sambas
Pontianak
Succadana
Billiton
Nayas I.
Pt. Piqueu
Pt. Battoova
Pt. Selerroo
Parkang
Se Pora
N. Poggy I.
S. Poggy I.
Pt. Redan
Engano
Telok Betung
Java Head
Cheringin
Palambangan
Cheribon
Batavia
Samarang
Gunong Gede
Gunong Pangerango
Gunong Salak
Mendoot
Chilatoo
Wine Compers Bay
Gunong Tangkoobanprahoo
Gunong Tilloo
Gunong Sindoor
Gunong Slamet
Gunong Prahoo
Gunong Sumbing
Gunong Merbabo
Gunong Merapi
Gunong Ungaran
Gunong Kendal
Gunong Prow
Gunong Lawoo
Gunong Wilis
Gunong Kawi
Gunong Arjoono
Gunong Semeroo
Gunong Tengger
Gunong Ardjoono
Gunong Ardjoono
Gunong Ardjoono


CHINA SEA
MINDORO
Balabac
Balabac Strait
MINDANAO
Illana Bay
CENTRAL LINE OF MINIMUM TOTAL INTENSITY
CENTRAL LINE OF NO DIP
Serangani I.
Sooloo Archipelago
CELEBES SEA
Sanguir
Salibabu I.
MORTY
MOLUCCAS PASSAGE
BORNEO
Macassar Strait
Tomini Bay
C. Talisse
BATCHIAN
CELEBES
XULLA ISLANDS
Tolu Bay
Xulla Besar
BOOROO
CERAM
Line of 1° Variation East
Bay of Bony
Macassar
Gimbyrna
Selayr
Flores Sea
Postilions
GREAT WATER MOSTERS
MADURA
JAVA
SUMBAWA
FLORES
TIMOR
LINE OF NO VARIATION
Sandal Wood I.
Roma I.
Rotte I.
5°
0°
10°
115°
120°
125°
130°



G. Newport, del. Ford & George, Lithographers, Hatton Garden. W. Wing, lith.